REPORT NO. CASD-NAS 73-003
CONTRACT NAS 8-29150

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LIFE SCIENCES PAYLOAD DEFINITION AND INTEGRATION STUDY (TASK C & D)

VOLUME II • PAYLOAD DEFINITION, INTEGRATION, AND PLANNING STUDIES

GENERAL DYNAMICS
Convair Aerospace Division

PRICES SUBJECT TO CHANGE

132 p.

VOLUME I	MANAGEMENT SUMMARY
VOLUME II	PAYLOAD DEFINITION, INTEGRATION, AND PLANNING STUDIES
VOLUME III	APPENDICES
VOLUME IV	PRELIMINARY EQUIPMENT ITEM SPECIFICATION CATALOG

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August 1973

Submitted to
National Aeronautics and Space Administration
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ACKNOWLEDGMENTS

This report consists of Volume I — Management Summary, Volume II — Payload Definition, Integration and Planning Studies, Volume III — Appendices, and Volume IV — Preliminary Equipment Item Specification Catalog.

The authors wish to express their appreciation to the entire Life Sciences Payload Integration Team composed of:

C. B. May, Contracting Officer's Representative, NASA/MSFC

R. W. Dunning	NASA/Headquarters
S. T. Taketa	NASA/Ames Research Center
J. A. Mason	NASA/Johnson Space Center

and to J. D. Hilchey, NASA/Marshall Space Flight Center, for their valuable assistance and cooperation throughout the entire course of this study.

The following General Dynamics Convair Aerospace personnel contributed to this program:

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LIST OF ACRONYMS

AAP	Apollo Applications Program
BEST	Bioexperiment Support & Transfer
BRSM	Bioresearch Support Module
cm	Cage Module
CORE	Common Operational Reserach Equipment
CVT	Concept Verification Test
DMS	Data Management System
EGG	Electrocardiogram
EC/LSS	Environmental Control/Life Support System
ECS	Environmental Control System
EI	Equipment Item
EPS	Electrical Power System
EU	Equipment Unit
FPE	Functional Program Element
HUM	Holding Unit Module
IMBLMS	Integrated Medical & Behavioral Laboratory Measurement System
LFB	Laminar Flow Bench
LSPD	Life Sciences Payload Definition
LS/PS	Life Support/Protective Systems
MSFN	Manned Space Flight Network
MSI	Man-Systems Integration
PCM	Pulse Code Modulated
PI	Principal Investigator
RAM	Research Applications Module
SRT	Supporting Research Technology
TCS	Thermal Control System

SECTION 1

INTRODUCTION

1.1 PROGRAM OBJECTIVES

The Life Sciences Payload Definition and Integration Study is an integral part of the overall space research payload definition activity of NASA. The primary objective of the NASA payload definition activity is to develop the program plans of the various scientific disciplines scheduled for space research. In pursuit of this objective, the Life Sciences Payload Definition and Integration Study evolved several baseline conceptual laboratory designs. These laboratory designs provided the first step toward detailed definition of potential Life Sciences research equipment requirements. These laboratory equipment requirements were in turn used to develop preliminary Life Sciences program plans.

1.2 OVERVIEW

The Life Sciences Payload Definition and Integration Study was composed of four major tasks, as shown in Figure 1-1. Tasks A & B, the laboratory definition phase, were the subject of a prior NASA study, NAS8-26468, (references 1, 2, 3). The laboratory definition phase included the establishment of research functions, equipment definitions, and conceptual baseline laboratory designs. These baseline laboratories were designated as Maxi-Nom, Mini-30, and Mini-7. The engineering effort was approximately 8 man-years. The outputs of Tasks A & B were used by the NASA Life Sciences Payload Integration Team to establish guidelines for Tasks C & D, the laboratory integration phase of the study. A brief review of Tasks A & B is presented in paragraph 1.6 to provide background continuity.

The Task C & D effort is the subject of this report. The Task C effort stressed the integration of the NASA selected laboratory designs with the shuttle sortie module. The Task D effort updated and developed costs that could be used by NASA for preliminary program planning. The engineering effort during this phase of the study was equivalent to 2 man-years.

1.3 TASK C & D OBJECTIVE

The primary objective of task C was to determine the compatibility of the selected baseline laboratories with the shuttle sortie module concept. The initial activity involved updating the laboratories' functional capabilities and related equipment items as directed by the NASA Life Sciences Payload Integration Team. The specifics of this NASA guidance are covered in paragraph 1.5. The second task of the compatibility analysis established the size and characteristics of the various sortie module subsystems (i.e., electrical power, crew EC/LSS, etc.) required to support the defined research capability of the baseline laboratories.

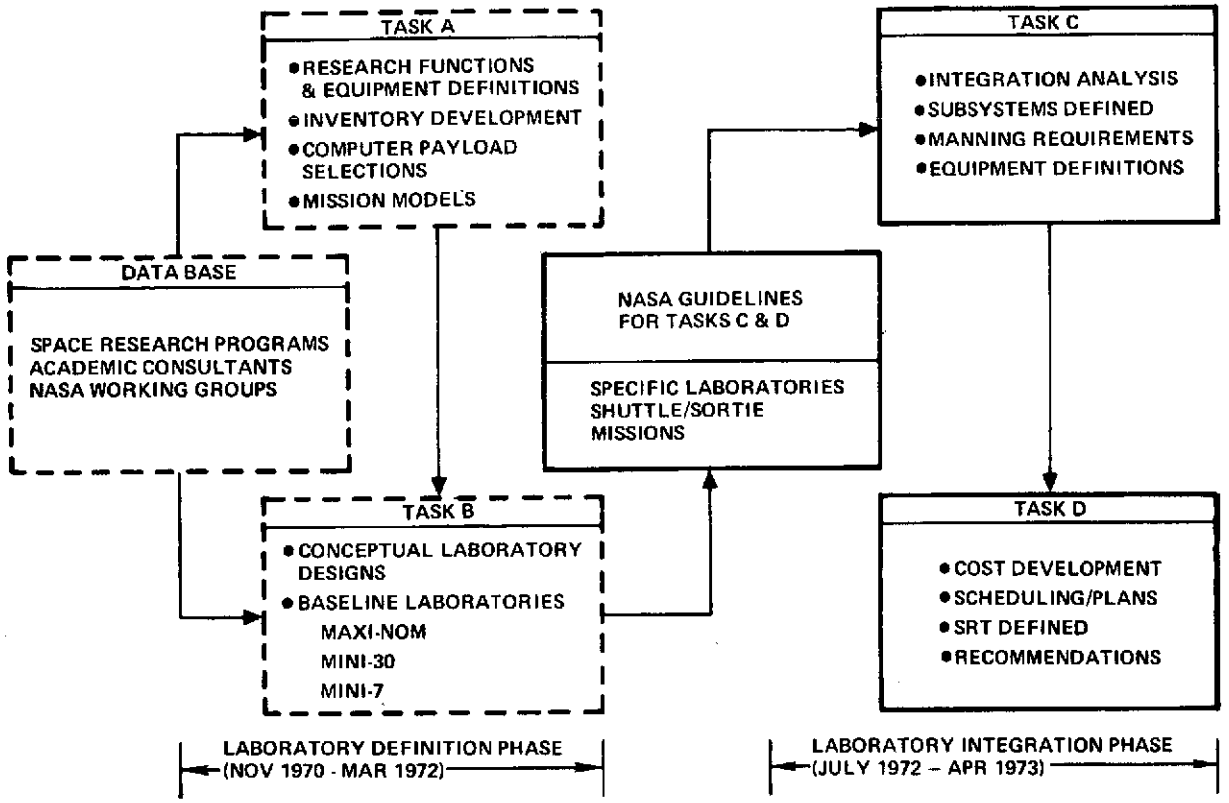


Figure 1-1. Program Overview

The Task D objective was to define preliminary program plans. This activity involved the determination of equipment cost profiles and development schedules to support flight opportunities in 1979 and beyond. Areas of significant supporting research and technology (SRT) were also identified.

1.4 DEFINITIONS

The following paragraphs describe the more important definitions used in this study. The Life Sciences discipline encompasses the functional program elements (FPE) of biomedicine, vertebrates, invertebrates, plants, and cells and tissues, man-systems integration, and life support and protective systems. The FPEs describe the grouping of experiments or experiment classes characterized by mutually supportive areas of research, which impose similar demands on the support module systems.

1.4.1 LIFE SCIENCES. Life Sciences research includes biomedicine, biology, man-systems integration, and life support/protective systems:

a. Biomedicine — Research devoted to (1) understanding character, time course and mechanisms of the physiological, anatomical, behavioral, and functional changes in man exposed to the space environment; and (2) providing the criteria for countermeasures in support of manned space flights.

b. Biology — Research devoted to (1) understanding the mechanisms of significant changes induced by the space environment on animals and cells and tissues as models wherein the investigation cannot be done easily on man; (2) understanding the graviperceptive mechanism and the role of gravity and biological periodicities (as influenced by time-varying environmental parameters) on various biological processes at the subcellular, cellular, tissue, organ, and organism levels; and (3) determining the biological effectiveness of galactic high-Z cosmic radiation particles. For the purpose of this study, biology will encompass research using vertebrates, invertebrates, plants, and cells and tissues as test subjects.

c. Man-System Integration (MSI) — Research devoted to (1) obtaining data on crew performance, integrated crew/equipment operations, and habitability; and (2) obtaining data to optimize man's ability to live and work in space.

d. Life Support and Protective Systems (LS/PS) — Research devoted to (1) obtaining data for advanced design of life support systems (LSS) and protective systems components and subsystems; (2) the establishment of design criteria,and (3) the development of the technology that will enable man to accomplish space missions effectively and safely.

1.4.2 LABORATORY EQUIPMENT ELEMENTS.

a. Equipment Item (EI) is the smallest hardware element defined within the various laboratories. In some cases an EI (such as a gas chromatograph) contains many individual components while other EIs are quite simple, such as a thermocouple.

b. Equipment Unit (EU) is a functional grouping of related equipment items. As an example, the items within the biochemical and biophysical EU include a gas chromatograph, mass spectrometer, and an atomic absorption spectrophotometer.

c. Common Operational Research Equipment (CORE) — Equipment or facility that serves many experimental areas in several Life Sciences FPEs. Examples are spectrophotometer, microscope, centrifuge, specimen preparation facility, and sample preservation units.

d. FPE-peculiar equipment — General-purpose equipment unique to a given Life Sciences FPE that can support various experiments on a reusable basis. Examples are the lower body negative pressure device, MSI task board, small vertebrate holding unit, and plant holding unit.

e. Experiment-peculiar equipment — Equipment designed specifically to support a given experiment and which is considered not to be reusable for another experiment without modification.

1.4.3 LABORATORY PAYLOADS DEFINED.

a. Shared 7-Day is a Life Sciences laboratory occupying approximately one-half the volume of a sortie module. The other half of the sortie module would be used by another scientific discipline.

b. Dedicated 7-Day is a laboratory (sortie module) devoted entirely to research in the Life Sciences area. The sortie module mission duration is seven days.

c. Dedicated 30-Day is a laboratory (sortie module) basically the same as the Dedicated 7-Day except that the mission duration is 30 days.

d. Carry-On Laboratories are portable, primarily self-contained Life Sciences laboratories that can be placed in the sortie module or the crew compartment of the shuttle orbiter.

1.5 GUIDELINES

NASA established study criteria in two general areas: the Life Science research payloads, and the supporting vehicle characteristics.

1.5.1 FUNCTIONAL CAPABILITY. The NASA review of the Task A & B outputs resulted in establishing the Mini-30 Laboratory as the area for primary emphasis. The equipment and research functions called out for this laboratory concept would provide the basic capability of both the Dedicated 7-Day and Dedicated 30-Day Laboratories. Secondary emphasis was placed upon the Shared 7-Day Laboratory. The Shared 7-Day Laboratory was based upon the Task A & B Mini-7 payload modified to include a factored-down Mini-30 capability in the areas of biomedical and vertebrate research and removal of the EVA research capability.

A second general category of research capability was described as the Carry-On Laboratories. Since the laboratories had not been studied during Task A & B, only conceptual designs were to be developed.

1.5.2 SORTIE MODULE. Some of the more significant sortie module characteristics used during this study are summarized in Table 1-1. The basic data was obtained from NASA-supplied references 4, 5 and 6.

1.6 BACKGROUND (REVIEW OF TASKS A & B)

The following is presented to provide a brief review of the previous program (NAS8-26468). More detailed information can be found in the final reports (references 1, 2, and 3) and in the introduction of Volume I of this report.

1.6.1 OBJECTIVES. The primary objective of Task A was to develop, from the existing broad base of data, a comprehensive and useful method of applying this data to laboratory designs. The Task B effort used this data to define a group of conceptual Life Sciences laboratories with varying degrees of research capability in biology, biomedicine, life support protective systems, and man-system integration.

1.6.2 GUIDELINES. The development of the laboratory concepts was based on a general facility approach rather than a specific experiment approach.

Table 1-1. Summary of Sortie Module Characteristics

Parameter	Description	
Internal Volume	87.8 m^3	(3,100 ft^3)
Diameter	4.26 m	(14 ft)
Length	7.31 m	(24 ft)
Allowable Payload	5,450 kg	(12,000 lb)
Average Power Available	4-5kW	
Electrical Energy	150 kW-hr	
Heat Rejection	4-5 kW_t	
Data Acquisition Rate	100 kbps	
Data Downlink Rate*	25-256 kbps	
Crew Size Accommodations		
Total in Orbit	4	
Sortie Module	2	

*Payload use is within this range; actual rate is dependent on shuttle orbiter use.

During Tasks A&B, a minimum number of mission constraints were placed upon the definition of the laboratories. Instead, research requirements were emphasized and engineering design concepts were defined to meet these requirements. This approach resulted in some payloads with broad capability that were completely responsive to all the scientists' desires. From these comprehensive payloads, lesser capability payloads were then defined with appropriate reduction in scientific responsiveness. Payloads were also defined base on an orderly growth and evolution from the lesser capability to the more comprehensive.

1.6.3 DATA BASE. The more significant items of the data base used during Task A & B are shown in Table 1-2. The concept was to build upon the foundation of past Life Sciences space research programs and to use this to establish the needs for the proposed laboratories of the future.

1.6.4 FUNCTION AND EQUIPMENT INVENTORIES. During Task A, research functions and related equipment items were defined for all the life sciences FPEs. Figure 1-2 is a summary of the characteristics of the function and equipment inventories developed. Counted individually, the functions total 1055. However, many of the functions were common to several FPEs, and considering this commonality, the number in the inventory is 455. These 455 functions can be performed by the 382 equipment items listed in the inventory. The equipment items have been grouped together in terms of their functional relationship designated as Equipment Units.

Seven Equipment Units designated CORE (Common Operational Research Equipment) are required totally or in part by all FPEs. Twenty Equipment Units are specific to one or more but not all the FPEs.

Table 1-2. Data Base

Documents	
Reference Earth Orbital Research & Applications Investigations	Convair
Earth Orbital Experiment Study	MDAC
Biotechnology Study	MDAC
IMBLMS	
B-3 Functional BB	LMSC/GE
Functional BB Performance Review	LMSC/GE
B-4 Statement of Work	NASA
Phase B Final Report	LMSC/GE
Experiment Module Concepts	Convair
Space Station/Base	MDAC/Martin & NR/GE
Orbital Workshop	Martin
Space Shuttle	Convair/NR
Human Performance Prediction	Bunker-Ramo
Advanced Integrated Life Support Systems	HSD
Communications & Working Papers	
Candidate Experiments & Common Use Equipment	ARC
Medical Measurements Requirements List	MSC
End-item Specifications for Inflight Medical Support System	MSC
Direct Communications & Working Papers	ARC/MSC/ MSFC/UCSD
Vendor/Mfg Specifications & Communications	

		BIOLOGY				BIOMED	LSPS	MAN SYSTEM INTEG. (MSI)	TOTAL	COMMON INVENTORY
		VERTE-BRATE	PLANT	INVERTE-BRATE	CELLS & TISSUE					
FUNCTIONS		276	106	95	93	276	79	130	1,055	455
EQUIPMENT ITEMS										382
EQUIPMENT UNITS	CORE	← 7 →								
	FPE	6	5	5	5	8	2	6	37	20

Figure 1-2. Inventory Summary

1.6.5 BASELINE LABORATORIES. The three laboratory baselines selected by NASA at the conclusion of Task B were repesentative of the early as well as the advanced capability laboratories. Table 1-3 summarizes the typical test subjects associated with these laboratories. The Mini-30 and Mini-7 were carried over into the Task C&D effort to undergo integration and planning analysis. The Maxi-Nom was not included in the follow-on activity.

Table 1-3. Summary of Baseline Payload Test Subjects

PFE and Test Subjects	Number of Test Subjects Aboard Baseline Payloads		
	Mini-7	Mini-30	Maxi-Nom
Biomedicine:			
Human Subjects	0	4	12
Vertebrates:			
Chimpanzees	0	0	0
Macaques	0	2	2
Rats	0	16 (2 cm)	128 (16 cm)
Plants:			
Marigolds	16 (1 cm)*	16 (1 cm)	128 (8 cm)
Invertebrates	(1 cm)	(1 cm)	(2 cm)
Cells and Tissues	(2 cm)	(2 cm)	(2 cm)
Life Support & Protective Systems:			
Hardware Test Units	1	1	1
Manned System Integration:			
Human Test Subjects	4	4	12

*Indicates the number of cage modules (cm) to support the organism.

1.7 APPROACH TO LABORATORY INTEGRATION

The approach used to define the integration and planning activity associated with the Life Sciences laboratories is shown in Figure 1-3. It includes (1) definition of research equipment, (2) review of sortie module resources available to support the research equipment, and (3) definition of additional subsystem equipment to be used to support the research equipment. These three activities led to the definition of preliminary laboratories and the generation of planning information such as costs and schedules.

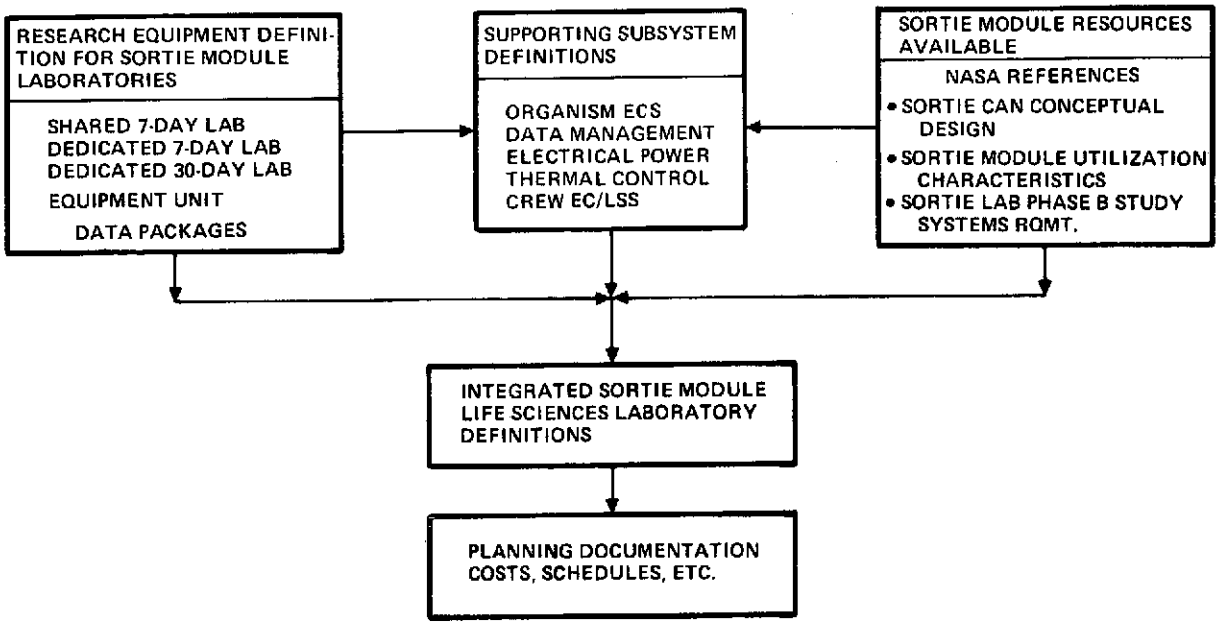


Figure 1-3. Laboratory Integration Study Flow Chart

Research equipment requirements were based on the Mini-7 and Mini-30 laboratory concepts defined in paragraph 1.6.5. The laboratory concepts were used in three missions of the shuttle/sortie module. These were designated (1) the Shared 7-Day Laboratory, (2) the Dedicated 7-Day Laboratory, and (3) the Dedicated 30-Day Laboratory. In defining the research equipment requirements of these laboratories, the equipment was grouped according to its function, and an equipment unit data package was formulated. The EU data package content is described in Section 2.1 of this report.

Essential to the operational use of the research equipment are the organism ECS, data management, electrical power, thermal control, and crew EC/LSS. These supporting subsystems were defined with respect to the research equipment requirements and the existing subsystems aboard the sortie module.

From the research equipment and subsystems studies, integrated laboratory definitions including layout drawings and overall laboratory properties were determined. Cost and schedules for the orderly development of Life Sciences Laboratories were also estimated.

SECTION 2

RESEARCH EQUIPMENT DEFINITION FOR SORTIE MODULE LABORATORIES

2.1 DESCRIPTION OF EQUIPMENT UNIT DATA PACKAGE CONTENT

This section discusses the research equipment within the Shared 7-Day Laboratory, the Dedicated 7-Day Laboratory and the Dedicated 30-Day Laboratory. In defining the research equipment requirements of these laboratories, the equipment was grouped according to its function, and equipment unit data packages were prepared. These data packages follow a common format and are contained in Appendix I, Volume III of this report. The general content of each of these data packages is summarized below. A more detailed description of the data packages is contained in Appendix I.

Table 2-1 shows the groups of equipment units for which equipment unit data packages have been prepared. An equipment unit (EU) is a group of equipment items (EIs) that pertain to the performance of common functions such as preparation and preservation of organisms and specimens.

The equipment units that pertain to general laboratory operations required by all the FPEs are designated common operational research equipment (CORE), and the others are designated FPE specific. These designations were derived in earlier studies and their use was continued in this study. In all, there are 14 equipment unit groups. These groups contain from about 5 to 30 equipment items.

Shown below is an outline of the kind of information to be found in the data packages in Appendix I, Section 1.2 through 1.15 for each equipment unit group.

(1) EU Functional Capability & Summary Data

    Summary of Weight, Power, Volume & Cost

(2) Equipment Items

    Equipment List

    Equipment Volume & Placement Figures

(3) Operations & Interfaces

    Equipment Operations Analysis

    Data Requirements

    Consumables

    Launch & Re-entry Operations

    Electrical Power

Table 2-1. Laboratory Equipment Unit Groups

EU No.	Name	
1	Visual Records & Microscopy Unit	Core Units
2	Data Management Unit	
3	Life Sciences Experiment Support Unit	
4	Preparation & Preservation Unit	
5	Biochemical & Biophysics Analysis Unit	
6/7	Maintenance Repair & Fabrication Unit/Ancillary Storage Unit	
11	Airlock/EVA Capability	FPE Specific Units
12/31	Biomedical/Behavorial Research Support Unit/ Biomedical Research Support Unit	
26	Radiobiology Support Unit	
40/41/42	Vertebrate Holding Unit/Primate Holding Unit/ Vertebrate Research Support Unit	
50/51/70	Plant Holding Unit/Plant Research Support Unit & Invertebrate Holding Unit	
60/61	Cells & Tissue Holding Unit/Cells & Tissues Research Support Unit	
80	Life Support Subsystem Test Unit	
91/93	Behavioral Measurements Unit/Mobility Unit	

Heat Rejection

Typical Equipment Unit Functional Interfaces

(4) Equipment Item Cost Summary

(1) EU Functional Capability and Summary Data. This category contains summary information of the functional capability of the equipment unit and a table of total weight, power, volume and cost.

(2) Equipment Items. Within this category is detailed information about each equipment item. This includes a listing of all the equipment items' pertinent properties and figures showing the volume and placement of these equipment items within standardized racks and consoles. In addition to the detailed information on categories (1) and (2) contained in Appendix I, summary information is also contained in Sections 2.2 and 2.3 of this report volume.

(3) Operations & Interfaces. In the area of operations and interfaces each EU data package contains information on an analytical operations model. This operations model was developed based upon the functions to be performed within the laboratories as listed in the functions inventory that was developed during Task A&B of the preceding contract. This permitted the calculation of

certain laboratory properties, such as electrical power use, while maintaining a facility approach to laboratory definition. The model is described in detail in Section 6. Data requirements of the research equipment are also contained in the data packages. These are discussed in detail in Section 3.2 on the Data Management Subsystem. Also included in the data packages is information on the consumables required within the equipment unit, and general information on any equipment requiring special consideration during launch or re-entry. Electrical power and heat rejection requirements of the equipment are presented. Typical research functional interrelationships between the equipment units are also described for most of the EUs. These are intended as an aid to the engineer in understanding how each equipment unit may be used by payload specialists, and what other equipment units interact with the subject equipment unit. This information is intended to aid in the proper placement of the equipment units within the overall laboratory.

(4) Equipment Item Cost Summary. The last item listed is the equipment item cost summary. The cost summary table indicates the type of development required as well as the time required for the development of a flight article. Each of the three sortie module laboratories is listed with unit and development costs for each individual EI and a summation for the total EU cost. Commercial costs for certain EIs are listed for comparison. When appropriate, remarks pertaining to the cost factors of an EI are included in the table.

2.2 GENERAL DESCRIPTION OF RESEARCH EQUIPMENT

The following sections contain brief descriptions of the functional capabilities and major equipment within each equipment unit group for which there is a data package in Appendix I. Summary data on weight, volume and power for these equipment units is presented in Section 2.3.

2.2.1 EQUIPMENT UNIT 1, VISUAL RECORDS AND MICROSCOPY UNIT. This equipment unit provides the capabilility for obtaining and preserving records of visual experiment phenomena and data. Major equipment items include movie cameras, still cameras, video cameras, a biomedical recorder and microscopes. Currently, none of the cameras or other equipment in EU 1 is anticipated to be operating during launch or re-entry phases of the mission. Any such requirements are considered to be experiment-specific and will be delineated when such experiments are to be flown. Major average power consumers are the camera controller and cameras.

2.2.2 EQUIPMENT UNIT 2, DATA MANAGEMENT UNIT. The equipment within this EU is intended to supplement the spacecraft data management subsystem (DMS) to provide the full capability to perform the Life Sciences research. Equipment in the EU includes a CRT camera, portable interrogative display and keyboard, and a portable oscilloscope. Small, general-purpose instrumentation is also included. A large data requirement results from the ECG couplers in this EU, which monitor ECG data continuously; see Section 3.2 for additional detail.

2.2.3 EQUIPMENT UNIT 3 — LIFE SCIENCES EXPERIMENT SUPPORT UNIT. This unit is intended to provide centralized supporting and vehicle interface equipment for the Life Sciences payloads. Major equipment includes crew mobility aids, crew restraints, gas storage vessels, and waste storage. The various gas storage vessels must be replaced between flights, but are all expected to be small, high-pressure gas storage bottles, which can be easily replaced.

2.2.4 EQUIPMENT UNIT 4 — PREPARATION AND PRESERVATION UNIT. This equipment unit provides the capability for the preparation and preservation of biological specimens and whole organisms. Preparation encompasses all the operations for (1) obtaining and preparing specimens for on-board analysis (often by means of equipment within the Biochemical/Biophysics Analysis Unit), and (2) preparing specimens or organisms for preservation and return to ground. This includes such operations as autopsies, dissections, centrifugation, anesthetization, staining, substrate preparation, sterilization, etc. Preservation operations include freezing, lyophilization, fixation, etc.

Major equipment items include the laminar flow bench, centrifuges, refrigerators, freezers, various kits, and mass measurement devices. Consumables in this EU include anesthetizer gas bottles, laminar flow bench liners, chemicals, ion exchange columns, kit materials, millipore filters, and liquid nitrogen (LN_2),which may have to be loaded aboard the laboratories several hours before launch. This N_2 would be continuously venting at an estimated rate of 0.8 pound/day.

It is anticipated that none of the equipment within this EU needs to be operating during launch (except for the cryogenic freezer; see above). The other refrigerators, freezers, purge system, etc., can be activated with the activation of the laboratory in orbit. It may prove advantageous and/or necessary to operate the refrigerators and freezers during launch operations prior to liftoff to maintain their contents at proper storage temperatures. Precooling this equipment would also reduce the energy requirements for its activation in orbit. However, during ascent and descent, it is anticipated that this equipment can be turned off if necessary. The thermal capacity and insulation of this equipment is expected to hold satisfactorily low temperatures during these relatively short phases of the mission.

2.2.5 EQUIPMENT UNIT 5 — BIOCHEMICAL/BIOPHYSICAL ANALYSIS UNIT. This unit performs the major measurements and analyses of experiment specimens and parameters, generally requiring more than simple instrumentation. These include measurements of blood and urine constituents and properties, gas compositions, and sound levels. Major equipment items inlcude an automatic blood analyzer, spectrophotometer, blood cell counter, blood gas analyzer, mass spectrometer, and gas chromatograph. Liquid nitrogen is required for the trace gas concentrator. Approximately 3 pounds/day have been estimated or 21 pounds for a 7-day mission, and 90 pounds for a 30-day mission. The trace gas concentator will require filling during launch operations. Other consumables include chemicals for the various analyzers

and bottled gas for the gas chromatograph. However, these are not time limited with respect to sortie launch operations. None of the equipment in this EU is expected to be functioning except during orbital experiment operations. Nitrogen boil-off from the freeze trap will have to be vented during launch.

2.2.6 EQUIPMENT UNIT GROUP 6/7 — MAINTENANCE, REPAIR & FABRICATION UNIT (6) AND ANCILLARY STORAGE UNIT (7). Equipment Unit 6 is intended to provide for maintenance, repair, or fabrication of payload equipment. For the short 7- and 30-day missions under consideration for the sortie module, the primary function will be one of maintenance, with minor emphasis on repair and fabrication. Equipment Unit 7 is ancillary storage space for primarily consumable items. Major equipment items in EU 6 include a hand cleansing and sterilization device, waste solids compactor, clean-up kit, tool kit, and electronic equipment for the maintenance and calibration of electrophysiological sensors. Equipment Unit 7 consists of storage cabinets.

2.2.7 EQUIPMENT UNIT 11 — AIRLOCK & EVA CAPABILITY. This equipment unit includes the major items required for EVA activities in support of Life Sciences testing. By NASA direction, EVA test activities will not be performed aboard the Shared 7-Day Laboratory. Therefore, EVA equipment is needed only aboard the dedicated laboratories. This equipment unit includes an airlock, teleoperator control console, and pressure suits. The shuttle orbiter airlock will be used for EVA. The sortie module has no provisions for a pressure suit ventilation circuit. Thus, portable life support systems (PLSS) backpacks will be used during suited tests. These are included in EU 80, Life Support Subsystem Test Unit.

2.2.8 EQUIPMENT UNIT GROUP 12/31 — BIOMEDICAL/BEHAVIORAL RESEARCH SUPPORT UNIT (12), AND BIOMEDICAL RESEARCH UNIT (31). These equipment units contain equipment intended to provide behavioral and biomedical research functions. Equipment Unit 31 contains equipment necessary for biomedical research but not needed for behavioral research. Equipment Unit 12 contains equipment necessary for both behavioral and biomedical research. In this way, if only behavioral research is to be performed aboard a payload, EU 12 is selected for inclusion in the payload complement of equipment. However, if biomedical research is to be done, both EU 12 and EU 31 are required. Major equipment items in EU 12/31 are the body mass measurement device, experimenter's control console, electrophysiology display, rotating litter chair, and bicycle ergometer.

2.2.9 EQUIPMENT UNIT 26 — RADIOBIOLOGY UNIT. This unit supports radiobiological studies and provides the capability for irradiating organisms or specimens, and measuring radioisotope tracers. Major equipment items are the radiation detector, radiation source and radiation source storage (in the Dedicated 30-Day Laboratory only), and radiation counter.

2.2.10 EQUIPMENT UNIT GROUP 40/41/42 — SMALL VERTEBRATE HOLDING UNIT (40), PRIMATE HOLDING UNIT (41), VERTEBRATE RESEARCH SUPPORT UNIT (42). This equipment unit provides for holding (caging) vertebrates as well as for research supporting functions specific to the vertebrate organisms. The environmental control equipment necessary for the support of the vertebrates is presented separately in Section 3.1 of this report. Major equipment items include two vertebrate cage modules, two primate cages (dedicated laboratories only), and metabolic mass balance measuring equipment. Consumables in these equipment units include urine and fecal collection pads and filters, food, and miscellaneous equipment within the veterinary kit. These are all small items for the mission durations being considered, and no special problems are anticipated. All these items are of the type that will not need replacement until the end of a particular flight. Water is a relatively large consumable but is included as part of the organism ECS.

Equipment Units 40 and 41 house the vertebrate organisms and therefore will require special launch and re-entry considerations. Among them are:

a. Organism should be placed aboard the sortie module as close to liftoff as is practical, and removed as soon after landing as practical.

b. While the organisms are aboard during launch operations, ascent, descent, and recovery, provisions should be available for monitoring the organisms. The launch phase during which they should be monitored and the type of monitoring will depend upon the particular experiment. At least TV and electrophysiological capability should be available if needed. Thus, the data management subsystem must be capable of operation during launch re-entry.

c. The ECS for the organisms must also be functioning during launch and recovery.

d. Orientation of the organisms with respect to gravitational, acceleration, and air drag forces is an aspect involving launch and re-entry operations that will need additional detailed study. The organisms will undergo various acceleration and gravitational forces in various directions throughout the flight. They must be kept as calm and quiet as possible to prevent injury and trauma, whether self-inflicted or externally caused. For this purpose, some form of restraint system has been assumed for this study. Many types of restraint and protection systems can be envisioned (harnesses, cushions, air bags, etc.), but the details of such a system are considered beyond the scope of this study. However, assuming that a restraint system is used, it will require emplacement prior to ascent and descent, and removal upon achieving orbit and upon organism ground recovery.

   Also, assuming that a restraint system is to be used allows the vertebrate cages (and cage modules) a greater degree of freedom in their orientation in the sortie module. That is, they are not constrained by the direction of the ascent and decent acceleration vectors so long as these vectors are compatible with the restraint system/cage design. The launch loads should be in a direction compatible with

organism comfort and safety, and also should be in a direction so that urination and defecation will not result in organism harm or functional damage to the caging system; e.g., saturation of food pellets, shorting of electrical connections, etc.

2.2.11 EQUIPMENT UNIT GROUP 50/51/70 — PLANT HOLDING UNIT (50), PLANT RESEARCH SUPPORT UNIT (51), INVERTBRATE HOLDING UNIT (70). These equipment units provide the environmental enclosures for the growth of plant organisms, invertebrate organisms, and the equipment to support plant research. Major equipment items include the plant holding unit (cage module), an enclosure for making metobolic mass balance measurements on plants, a clinostat, a plant tool kit, and a holding unit for invertbrates. Launch and re-entry considerations for the plants and invertebrates are similar to those for the vertebrates; see Section 2.2.10. The organisms should be loaded as late in the launch sequence as practical and recovered as soon after landing as practical. Depending upon the experiment, some data management equipment may be required during ascent and descent. Ascent and descent acceleration and vibration forces will probably require special protective devices during these mission phases. The plant supports will require emplacement prior to descent and ascent, and removal upon achieving orbit and landing.

2.2.12 EQUIPMENT UNIT GROUP 60/61 — CELLS AND TISSUES HOLDING UNIT (60), AND CELLS AND TISSUES RESEARCH SUPPORT UNIT (61). These equipment units provide for the housing of cells and tissues as well as supporting research in these areas. The major equipment includes two holding units (cage modules) for cells and tissues. As with the other organisms, any cells and tissues being launched should be loaded as late as practical in the launch sequence and recovered as soon as possible upon return. DMS and ECS support may or may not be required during ascent and descent, depending upon the particular experiment.

2.2.13 EQUIPMENT UNIT 80 — LIFE SUPPORT SUBSYSTEM TEST UNIT. This equipment unit provides the capability to perform tests on LSS prototype equipment. Major equipment includes portable life support systems for EVA, and an LSS test bench. The latter is intended to provide support for a variety of experimental test apparatus. Such support would include electrical power connections, coolant fluid connections, structural support, vacuum connections, and general purpose instrumentation.

2.2.14 EQUIPMENT UNIT GROUP 91/93 — MAN-SYSTEMS INTEGRATION (MSI) MEASUREMENTS UNIT (91) AND MOBILITY UNIT (93). These equipment units provide the capability to test man's behavior and performance in space and his interaction with various types of equipment. Major equipment items are the psychomotor performance console, the force/torque measurement taskboard, the vision tester, protective corridor devices, and the EVA, MSI task simulator (required only on the dedicated laboratories).

2.3 SUMMARY DATA FOR RESEARCH EQUIPMENT

The weight, power, and volume characteristics of the research equipment within the Life Sciences Laboratories is presented in the following paragraphs of this section. Summary data on costs and data requirements for the research equipment are presented separately in Sections 8.0 and 3.2, respectively.

2.3.1 RESEARCH EQUIPMENT WEIGHT. The weight of the research equipment within each EU group is shown in Table 2-2. A weight allowance has been added for each laboratory to account for the racks and consoles used to house most of the research equipment. Preliminary analysis conducted during Tasks A and B indicated that a standard rack or console would weigh approximately 30 kg (66 lb). Therefore, this value was used in this study. For research equipment not mounted in racks and consoles, such as the rotating litter chair, the weight of the item itself was assumed to include the necessary mounting supports, brackets, etc.

The weight of the Dedicated 7-Day Laboratory increases over that of the Shared Laboratory because of a substantial increase in research equipment. The Dedicated 30-Day Laboratory increases over the Dedicated 7-Day Laboratory because of a slight increase in research capability, but mainly because of the extra consumables required.

Table 2-2. Life Sciences Laboratory Research Equipment Weight Summary

EU No.	Equipment Units	Equipment Weight, kg		
		Shared 7-Day Lab.	Dedicated 7-Day Lab.	Dedicated 30-Day Lab.
1	Visual Records & Microscopy	181	258	299
2	Data Management	34	84	84
3	Life Sciences Experiment Unit	157	195	255
4	Preparation and Preservation	316	360	533
5	Biochemical/Biophysical Analysis	230	453	582
6/7	Maintenance, Repair/Storage	94	156	331
11	Airlock/EVA Capability	0	235	235
12/31	Biomedical/Behavior Support	326	383	383
26	Radiobiology Support	114	115	183
40/41/42	Vertebrate Holding & Support	210	330	380
50/51/70	Plant Holding & Support/Invertebrates	112	125	125
60/61	Cells and Tissues	74	74	78
80	LSS Test Unit	54	114	114
90/91	MSI Measurements/Mobility	72	118	142
	Subtotals	1974	3000	3724
	Racks & Consoles @ 30 kg each	210 (7)	300 (10)	360 (12)
	Totals	2184 kg (4804 lb)	3300 kg (7260 lb)	4084 kg (8985 lb)

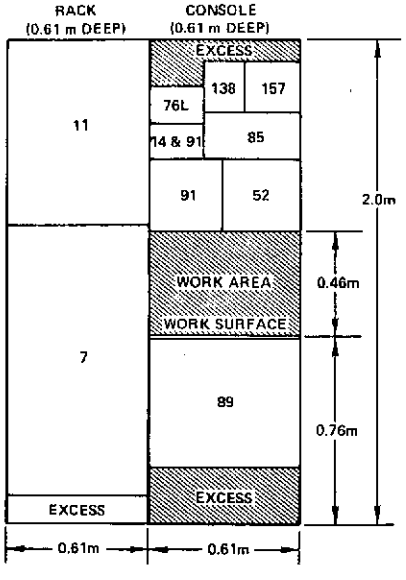
2.3.2 RESEARCH EQUIPMENT VOLUME. The standard-sized racks and consoles developed during Tasks A and B were used to hold the research equipment. The outlines of a rack and console are shown in Figure 2-1. Each is 0.61 × 0.61 × 2.0 meters.

The equipment items in each EU were conceptually placed in the racks and consoles as shown in the example in the figure. The excess volume represents an allowance for improper fit, room for brackets, etc., within the console and the console volume itself. The names and volumes of each EI are listed in the tabulation to the left on the figure. Note that a cubic decimeter is approximately equal to one liter (≈1 quart), and there are 1000 dm^3 per m^3 and 28.3 dm^3 per cubic foot. To the right of the figure is a list of EIs within EU 5 that are distributed around the laboratory because of their specific function.

Using the placement and volume data for each EU within the three laboratories, summaries were prepared as shown in Tables 2-3, 2-4, and 2-5. These tables show the number of racks or consoles needed to house the research equipment within each EU group and the resulting volume of the racks or consoles. The tables also list the storage volume required for several small and special EIs. These could be placed in ancillary storage (EU 7) or in miscellaneous storage areas within the sortie module. Distributed items are those not amenable to placement in racks or consoles. The volume of these items is tabulated along with a brief description of the major items within this category; see Figure 2-1. The volume of the racks and consoles added to the volume of the extra and storage items makes up the total research equipment volume aboard the sortie module.

EQUIPMENT ITEMS IN RACK & CONSOLE

E.I. NUMBER & NAME		VOL. dm^3
IN RACK:		
7	AUTOANALYZER	425
11	SPECTROPHOTOMETER	283
	TOTAL	708
	EXCESS VOL. ALLOWANCE	36
IN TOP OF CONSOLE:		
52	CELL COUNTER	57
54	COLONY COUNTER	14
70L	FIBROMETER	20
85	BLOOD GAS ANALYZER	45
90	MASS SPECTROMETER	57
91	MASS SPECTROMETER (1)	6
138	pH METER	23
157	SOUND METER	28
	TOTAL	250
	EXCESS VOL. ALLOWANCE	40
IN BOTTOM OF CONSOLE:		
89	GAS CHROMATOGRAPH	207
125C, 126B, 179A	REFRACTOMETER, MICROPHONES (5), THERMOCOUPLES	1 (NEGL.)
	TOTAL	208
	EXCESS VOL. ALLOWANCE	75



DISTRIBUTED OR EXTRA EQUIPMENT ITEMS (NOT IN RACK OR CONSOLE)

E.I. NUMBER & NAME		VOL. dm^3
15A	GAS MANIFOLD	28
50A	MANIFOLD FLOW CONTROL	14
86	CO_2 ANALYZER	1
91	MASS SPECTROMETER (1)	6
93	DEW POINT SENSORS	104
125B	METERS (MISC.)	1
125C	AMPLIFIERS	NEGL.
180A	TRACE GAS CONCENTRATOR	28
	TOTAL	182

SMALL STORAGE EQUIPMENT ITEMS

(CAN BE STORED IN MISCELLANEOUS SMALL STORAGE AREAS)

E.I. NUMBER & NAME	VOL. dm^3
NONE	

Figure 2-1. Sample Equipment Volume and Placement. Figure from EU Data Package — EU 5, Biochemical/Biophysical Analysis Unit, Dedicated 7-Day Laboratory

Table 2-3. Summary of Payload Research Equipment Volume, Shared 7-Day Laboratory

EU No.	Equipment Units	Racks or Consoles		Storage	Distributed or Extra Items	
		No.	Vol, dm^3	Vol, dm^3	Vol, dm^3	Description of Major Items
1	Visual Records and Microscopy	1/2	372	0	74	Video Equipment
2	Data Management	0	0	0	86	Display
3	Life Sciences Experiment Unit	0	0	0	237	Gas Vessels & Crew Restraints
4	Preparation & Preservation	2	1488	0	576	Laminar Flow Bench
5	Biochemical & Biophysical Analysis	1	744	0	137	Gas Analysis Equipment
6/7	Maintenance, Repair/Storage	1	744	0	0	
11	Airlock & EVA Capability	0	0	0	0	
12/31	Biomedical/Behavioral Support	1	744	0	4388	Ergometer, Litter Chair, Body Mass Measurement
26	Radiobiology Support	1/2	372	0	0	
40/41/42	Vertebrate Holding & Support	0	0	56	376	2 Cage Modules & 2 Monkey Containers
50/51/70	Plant Holding & Support/Invertebrates	0	0	216	376	2 Cage Modules
60/61	Cells & Tissues	0	0	14	376	2 Cage Modules
80	LSS Test Unit	1/2	372	0	57	Manifold
90/91	MSI Measurements/Mobility	1/2	372	0	0	
	Totals	7	5208	286	6683	

Total Laboratory Research Equipment Volume . . . . . 12.18 m^3 (430 ft^3)

Table 2-4. Summary of Payload Research Equipment Volume, Dedicated 7-Day Laboratory

EU No.	Equipment Unit Group	Racks or Consoles		Storage	Distributed or Extra Items	
		No.	Vol, dm^3	Vol, dm^3	Vol, dm^3	Description of Major Items
1	Visual Records & Microscopy	1/2	372	0	91	Video Equipment
2	Data Management	0	0	0	188	Electronics
3	Life Sciences Experiment Unit	0	0	0	324	Gas Vessels & Crew Restraints
4	Preparation & Preservation	2	1488	0	579	Laminar Flow Bench
5	Biochemical & Biophysical Analysis	2	1488	0	183	Gas Analysis Equipment
6/7	Maintenance, Repair/Storage	1	744	0	0	
11	Airlock & EVA Capability	1	744	0	283	Teleoperator Console
12/31	Biomedical/Behavioral Support	1-1/2	1116	0	4388	Ergometer, Litter Chair, Body Mass Measurement
26	Radiobiology Support	1/2	372	0	0	
40/41/42	Vertebrate Holding & Support	0	0	69	1508	2 Cage Modules & 2 Monkey Containers
50/51/70	Plant Holding and Support/Invertebrates	0	0	216	376	2 Cage Modules
60/61	Cells & Tissues	0	0	14	376	2 Cage Modules
80	LSS Test Unit	1	744	0	57	Manifold
90/91	MSI Measurements	1/2	372	0	566	Task Simulator
	Total	10	7440	299	8919	

Total Laboratory Research Equipment Volume . . . . . 16.66 m^3 (589 ft^3)

Table 2-5. Summary of Payload Research Equipment Volume, Dedicated 30-Day Laboratory

EU No.	Equipment Unit Group	Racks or Consoles No.	Racks or Consoles Vol. dm^3	Storage Vol. dm^3	Distributed or Extra Items Vol. dm^3	Distributed or Extra Items Description of Major Items
1	Visual Records & Microscopy	½	372	0	91	Video Equipment
2	Data Management	0	0	0	188	Electronics
3	Life Sciences Experiment Unit	0	0	0	472	Gas Vessels & Crew Restraints
4	Preparation & Preservation	3	2232	0	587	Laminar Flow Bench
5	Biochemical & Biophysical Analysis	2½	1860	0	239	Gas Analysis Equipment
6/7	Maintenance, Repair/Storage	1½	1116	0	0	
11	Airlock & EVA Capability	1	744	0	238	Teleoperator Console
12/31	Biomedical/Behavioral Support	1-1/2	1116	0	4388	Ergometer, Litter Chair, Body Mass Meas.
26	Radiobiology Support	½	372	0	0	--
40/41/42	Vertebrate Holding and Support	0	0	69	1600	2 Cage Modules & 2 Monkey Containers
50/51/70	Plant Holding and Support/Invertebrates	0	0	216	376	2 Cage Modules
60/61	Cells & Tissues	0	0	28	376	2 Cage Modules
80	LSS Test Unit	1	744	0	57	Manifold
90/91	M.S.I. Measurements/Mobility	1/2	372	0	679	Task Simulator
	Totals	12	8928	313	9291	
	Total Laboratory Research Equipment Vol.			18.53 m^3 (655 ft^3)		

2.3.3 RESEARCH EQUIPMENT POWER REQUIREMENTS. Averaged power requirements for all the research equipment was obtained from the operations model tables, an example of which is shown in Section 6, Table 6-1. A summary of these average power requirements for each equipment unit group is shown in Table 2-6. Off-duty power is that generally associated with continuously operating equipment or automatic equipment. On-duty power includes the requirements of the equipment used by the payload specialists during their 12-hour period in attendance of experiments within the sortie module. A 24-hour average value is also shown and was used in preliminary calculations on electrical power subsystem fuel requirements and thermal control subsystem loads.

Table 2-6. Summary of Electrical Power Consumption of the Research Equipment

EU No.	Equipment Units	Average Electrical Power Consumption, w.					
		Shared 7-Day Lab.		Dedicated 7-Day Lab.		Dedicated 30-Day Lab.	
		On Duty*	Off Duty*	On Duty*	Off Duty*	On Duty*	Off Duty*
1	Visual Records & Microscopy	224	219	261	237	271	246
2	Data Management	103	100	155	146	155	146
3	Life Sciences Experiment Unit	20	20	65	64	65	64
4	Preparation and Preservation	257	85	277	85	541	335
5	Biochemical/Biophysical Analysis	88	80	315	225	320	225
6/7	Maintenance, Repair/Storage	10	0	27	0	27	0
11	Airlock/EVA Capability	0	0	0	0	0	0
12/31	Biomedical/Behavioral Support	26	6	56	6	56	6
26	Radiobiology Support	5	0	14	0	15	0
40/41/42	Vertebrate Holding & Support	82	82	195	195	230	230
50/51/70	Plant Holding & Support/Invertebrates	130	130	131	130	131	130
60/61	Cells and Tissues	100	100	100	100	100	100
80	LSS Test Unit	200	200	200	200	200	200
90/91	MSI Measurements/Mobility	0	0	2	0	4	0
TOTALS		1245	1022	1798	1388	2115	1682
24-Hour Average Power Consumption		1134		1593		1899	

*12 Hours

SECTION 3

SUPPORTING SUBSYSTEM DEFINITIONS

In the preceding section, the research equipment contained in the Shared 7-Day, Dedicated 7-Day, and Dedicated 30-Day Laboratories has been discussed. These laboratories and their equipment are contained in and supported by the sortie module, described previously in Section 1.5. The sortie module contains certain baseline subsystems for the supply of electrical power, data management, and thermal control support to the research equipment and processes. These subsystems were reviewed during this study to determine whether the baseline sortie module could adequately support the Life Sciences research equipment. In addition to the baseline sortie module subsystems, an organism environmental control subsystem (ECS) is needed for the organisms aboard the laboratories. This was also studied.

The results of the various subsystem studies are described in the following sections.

3.1 ORGANISM ENVIRONMENTAL CONTROL SUBSYSTEM

3.1.1 REQUIREMENTS. The organism environmental control subsystem (ECS)* design depends upon organism metabolic rates. The metabolic data used in these studies are given in Table 3-1. They are based on the data presented in Reference 7, and are estimated to be conservative (high). The total quantities of organisms indicated are based on multiples that can be housed in a standard organism-holding unit referred to as a cage module.

The cage module concept has been developed by Convair Aerospace and can be used, with modifications, to house small vertebrates, invertebrates, plants, or cells/tissues. It is a closed but ventilated cabinet approximately 0.6m high × 0.7m wide × 0.6m deep. It is intended to operate at a slight negative pressure relative to the cabin to prevent contamination of the manned compartment of the sortie module. The closed nature of the cage module can also provide isolation between different groups of experiment organisms. When the doors are open for performing experiments, the cage module is intended to be mated with a laminar flow bench (glove box) to further minimize the possibility of cabin contamination. The cage module, containing 8 cages for rats, is shown in Figure 3-1.

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*The term organism ECS, rather than organism EC/LSS, has been used throughout this report, since the subject subsystem is primarily devoted to environmental control rather than life support functions.

Table 3-1. Metabolic Data Used for ECS Design Concepts

	DEDICATED AND SHARED LABORATORIES								DEDICATED ONLY	
	1 Plant Cage Module, 16 Sunflowers (5 g dry each, 57 µl CO_2/100 mg dry weight per hour)		1 Invertebrate Cage Module, 10,000 Fruit Flies (prepupa, 2.15 mg ea., 3.68µl O_2/hr each)		2 Cells & Tissues Cage Modules, 5 g dry weight Rat Tissue in each (8.75 mm O_2/mg dry weight per hour)		2 Vertebrate Cage Modules, 16 Rats (350 g body weight each)		2 Primate Containers, 2 Macaques (9.1 kg each)	
1. OXYGEN CONSUMPTION										
g/day (lb/day)	-1.56	(-0.0035)	+1.26	(+0.0028)	+3.0	(+0.0067)	+288	(+0.634)	+411	(+0.905)
g/7 days (lb/7 days)	-10.9	(-0.024)	+8.82	(+0.0194)	+21.0	(+0.0467)	+2016	(+4.44)	+2877	(+6.34)
2. CO_2 PRODUCTION										
g/day (1b/day)	-2.14	(-0.0047)	+1.73	(+0.0038)	+4.12	(+0.0091)	+338	(+0.744)	+481	(+1.06)
g/7 days (1b/7 days)	-15.0	(-0.033)	+12.1	(+0.0267	+28.8	(+0.064)	+2366	(+5.21	+3370	(+7.42)
3. LIOH CANISTERS REQUIRED										
g/day (lb/day)	-2.85	(-0.0063)	+2.3	(+0.0051)	+5.48	(+0.012)	+450	(+0.991)	+645	(+1.42)
g/7 days (lb/7 days)	-20.0	(-0.044)	+16.1	(+0.035)	+38.4	(+0.084)	+3150	(+6.94)	+4510	(+9.94)
cc/7 days (ft^3/7 days)	-49.8	(0.0018)	+39.6	(+0.0014)	+95.2	(+0.0034)	+7860	(+0.277)	+11,200	(+0.396)
4. FOOD REQUIRED										
g/day (lb/day)	in media		negl.		included in media		+208	(+0.458)	+306	(+0.674)
g/7 days (lb/7 days)							+1460	(+3.21)	+2140	(+4.72)
cc/7 days (ft^3/7 days)							+1040	(+0.0369)	+1533	(+0.0541)
5. FECES PRODUCED										
g/day (lb/day)	--		--		--		+51.8	(+0.114)	+76.7	(+0.169)
g/7 days (lb/7 days)							+362	(+0.798)	+537	(+1.18)
cc/7 days (ft^3/7 days)							+362	(+0.013)	+536	(+0.019)
6. DRINKING WATER REQUIRED										
g/day (lb/day)	1.5 liter/wk maximum was assumed for plant watering		negl.		negl.		+699	(+1.54)	+1090	(+2.41)
g/7 days (lb/7 days)							+4890	(+10.8)	+7660	(+16.9)
cc/7 days (ft^3/7 days)							+4880	(+0.172)	+7640	(+0.270)
7. WATER TURN-OVER*										
g/day (lb/day)	--		--		--		+828	(+1.82)	+1280	(+2.82)
g/7 days (lb/7 days)							+5800	(+12.7)	+8950	(+19.7)
cc/7 days (ft^3/7 days)							+827	(+0.0292)	+1280	(+0.0451)
8. HEAT OUTPUT										
Sensible Heat J/s (btu/hr)	negl.		negl.		negl.		27.2	(92.8)	46.4	(158)
Latent Heat J/s (Btu/hr)	"		"		"		15.0	(51.2)	12.8	(43.6)
Total Heat J/s (Btu/hr)	"		"		"		42.2	(144.0)	59.2	(202)

*Water output in urine, respiration, perspiration, and feces.

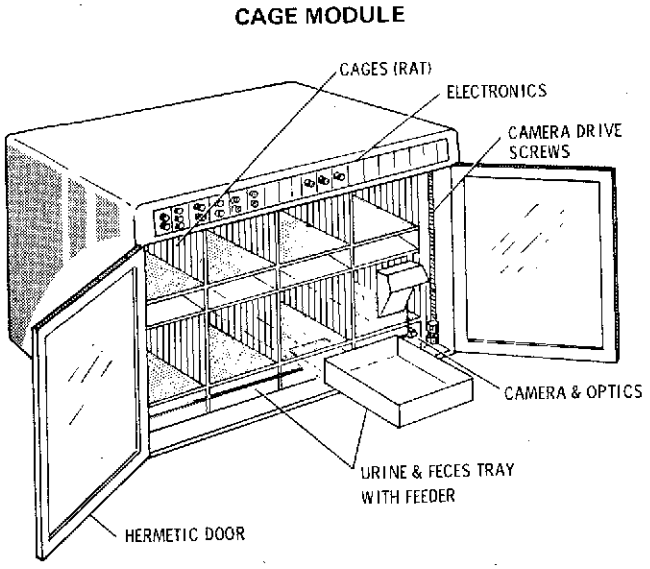


Figure 3-1. Cage Module

Table 3-1 also indicates the organism load aboard each of the three Life Sciences Laboratories. As shown, the Shared 7-Day, the Dedicated 7-Day, and the Dedicated 30-Day Laboratories all have:

1 plant cage module

1 invertebrate cage module

2 cells/tissues cage modules, and

2 small vertebrate cage modules.

In addition, the dedicated laboratories have 2 primate containers.

The type and quantity of organisms indicated in the table for each cage module and the primate cylinders were used as the basis for the ECS design calculations.

The plant, invertebrate, and cells and tissues loads are quite small and are based on the organisms indicated in the table. These rates are quite variable, depending upon the type of organisms and number contained in the cage modules. However, since the resulting metabolic loads on the ECS are so small, a large design margin can be provided so that the variability should not require major design changes in the ECS. Such a margin has been included in the preliminary ECS concepts and their weight, power and volume allocations. As an example, the oxygen required for the plants, invertebrates, and cells and tissues for 7 days is 18.9 g (0.042 lb) as obtained by adding the values in Table 3-1. However, approximately 0.20 kg (0.4 lb) of oxygen was included in the ECS allowance for these organisms. Hence, a great deal of over-capacity can be included without any appreciable impact on the overall weight of the payload. Also, the system for 7 days is also adequate for the 30-day mission. As indicated in Table 3-1, the nutrient and water requirements for the plants, invertebrates and cells and tissues are negligible.

For the small vertebrates, rats were used to size the ECS. Rats have a fairly high metabolic rate, and the use of other organisms within the cage modules is not expected to result in significantly larger loads on the ECS than those produced by rats. Also, a fairly large rat (350 grams) was used as the basis for the values shown in Table 3-1. As indicated in the table, 16 rats (2 cage modules) require 2.0 kg of O_2, 3.2 kg of LiOH, 1.5 kg of food, and 4.9 kg of water for 7 days. The primate data is based on 2 macaque monkeys weighing 9.1 kg each. They require about 50% more oxygen, LiOH, food, and water than the 16 rats. The total metabolic quantities for the vertebrates for both 7-day and 30-day missions are summarized in Table 3-2. A comparison between the metabolic oxygen and heat output of the small vertebrates and man is shown in Table 3-3.

Table 3-2. Summary of Design Metabolic Quantities Used for the Vertebrates Aboard the Sortie Module Laboratories

Metabolic Requirement	Totals for 7-Day Labs		Totals for Dedicated 30-Day Lab (kg)
	Shared (kg)	Dedicated (kg)	
O_2 Consumption	2.0	4.9	21.0
CO_2 Production	2.4	5.7	24.6
LiOH Needed (incl. canisters)	3.2	7.7	32.8
Food Consumption	1.5	3.6	15.5
Feces Produced	0.4	0.9	3.9
Drinking Water	4.9	12.5	53.7

Table 3-3. Metabolic Data for Monkeys and Rats Compared to that of Man

Organism	Body Wt. KG	O_2 Consumption		Heat Output	
		KG/day	Animals per Man	K Joules/day	Animals per Man
Astronaut	72	0.84	1.0	11,900	1.0
Monkey	9.1	0.20	4.1	2,560	4.6
Rat	0.35	0.018	46.3	230	51.8

3.1.2 VERTEBRATE ECS CONCEPTS. The vertebrates considered in this section include both the small vertebrates and the primates. Two cage modules of small vertibrates are contained in all the payloads being considered. In addition, the dedicated payloads contain 2 primates, each housed in a separate cage, with an external cylindrical shape.

3.1.2.1 Small Vertebrate ECS. It was assumed that the two cage modules (containing 16 rats) could share common ECS components and be connected in parallel to a common ventilation loop, which is shown in Figure 3-2 and includes LiOH for CO_2 removal, a condenser/separator for dehumidification and cooling, and blowers for circulation. Condenser accumulators, fresh water tanks, and high pressure oxygen are also used. Each cage module contains 8 rats in individual cages, which are ventilated in parallel. Each cage contains feeding and watering equipment, as well as a urine and fecal collection filter pad. It was also assumed that charcoal filters were contained in the cages for the removal of gaseous trace contaminants from the air stream leaving each cage. Placement of the charcoal filters in the 16 cages makes available a large total cross-sectional flow area and minimizes pressure drop through the charcoal compared to the placement of a smaller filter in the processing loop ducting. Also, design of the charcoal integral with the cage filters provides a convenient means of replacement. That is, when the urine pad filters are replaced, the charcoal can be replaced simultaneously.

The LiOH canister is placed in parallel with the loop blowers to minimize canister size as well as pressure drop. The flow through the canister depends upon the CO_2 removal efficiency and the loop CO_2 content. Assuming a drop in CO_2 partial pressure of 267 N/m^2 (2 mm Hg) through the LiOH, the canister air flow required is 0.49 g/sec (3.9 lb/hr and 0.87 cfm at 70°F and 14.7 psia).

Humidity is controlled in the cage modules by controlling the amount of coolant flowing through the cooler/condenser, which in turn controls the dew point temperature of the air leaving the cooler. The air temperature is controlled by varying the ratio of air bypassing the cooler to that flowing through it. This preliminary concept is based on an approximate heat loads analysis without detailed analysis of parasitic loads and off-design conditions. Such considerations would have to be analyzed before a final ECS

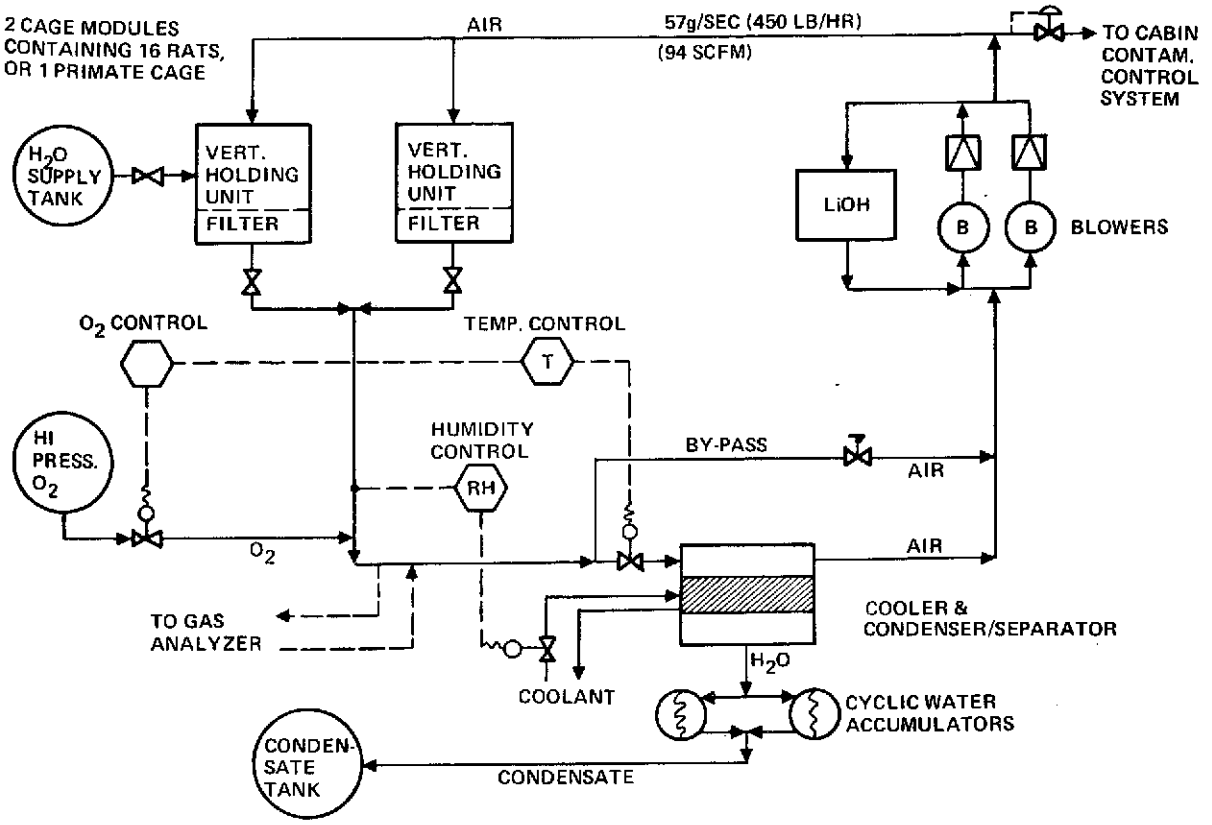


Figure 3-2. ECS Loop Concept for Vertebrate Holding Units

loop and control system configuration can be determined. Silica gel was also considered for dehumidifying the ECS loop air. Approximately 4 grams of silica gel per gram of water would be required, and its specific volume is 1.6 cc/g. The total water turnover (see Table 3-1) represents the total dehumidification load and results in the following:

	Total Water Turnover	Total Silica Gel Req'd	
	kg	kg	dm^3 (ft^3)
Shared 7-Day Lab	5.8	23.2	37 (1.3)
Dedicated 7-Day Lab	14.8	59.2	95 (3.4)
Dedicated 30-Day Lab	63.2	253	404 (14.3)

Although the quantities for the 7-day missions are not excessive, the quantity for 30 days was considered too heavy and bulky for use. (The laboratory weight for the 30-day mission exceeds sortie module launch weight capability.) Therefore, in the interest of making all three systems common, the silica gel was not selected for use.

Preliminary weight, volume, and power estimates for the environmental control loop components and consumables for the two small vertebrate cage modules are shown in Table 3-4. For 7 days, the total requirements are 43 kg (95 lb), 118 dm^3 (4.18 ft^3), and 110 watts. For the 30 day mission, 3 additional water supply tanks (of approximate 7-day capacity) are needed to supply drinking water. These tanks, when empty, are used to store condensate. Consumable supplies of drinking water, food, LiOH, and oxygen are also increased for the 30-day mission. The total requirements are 100 kg

Table 3-4. Preliminary ECS Weight, Power, and Volume for Two Small Vertebrate Cage Modules

Item	Weight, kg	Volume, dm^3	Ave. Power, watts
Fixed Hardware for 7 Days:			
Ducts and Tubing	5	63.7	0
Duct & Tubing Valves	3	4.8	0
Condenser & Controller	4	8.0	5
Condensate Cyclic Accumulator Assy.	1	2.0	0
Condensate Collection Tank (1)	1	8.0	0
Water Supply Tank (1)	1	8.0	0
Blowers (2 included)	9	9.0	100
Total Fixed Hardware for 7 Days	24	103.5	105
Consumables for 7 Days:			
Drinking Water	6	in tank	0
Food	2	in cm*	0
LiOH Canisters	3	7.8	0
Oxygen + Tankage + Controller	8	6.9	5
Total Consumables for 7 Days	19	14.7	5
Grand Total for 7 Days	43 (94.6 lb)	118.2 (4.18 ft^3)	110
Add-on Fixed Hardware for 30 Days:			
Water Supply Tanks (3)	3	24.0	0
Total Fixed Hardware for 30 Days	27	127.5	110
Consumables for 30 Days:			
Drinking Water	24	in tank	0
Food**	7	3.4	0
LiOH Canisters	14	33.6	0
Oxygen + Tankage	28	25.3	0
Total Consumables for 30 Days	73	62.3	0
Grand Total for 30 Days	100 (220 lbs)	189.8 (6.71 ft^3)	110

*cm = cage module
**Food volume shown is that of stored food for 29 days. The volume of food for 7 days is contained within the cage module (cm).

(220 lb), 190 dm^3 (6.71 ft^3), and 110 watts. Power for lighting is excluded here, since it is included in the power allocation for the individual organism cages, and is included in laboratory research equipment.

3.1.2.2 Primate ECS. The primate ECS requirements are sufficiently similar to those for the small vertebrates housed in the cage modules that the same ECS loop can be used. One loop, as described above, was used for each primate cage. The flow schematic is identified except for the substitution of one primate cage for the two vertegrate cage modules shown in Figure 3-2.

A weight, volume, and power breakdown for the two ECS loops supporting the two primate cages is given in Table 3-5. The fixed hardware for 7 days is identical to that used for the two small vertebrate cage modules. Consumables are slightly higher since the metabolic load of 2 macaques is greater than that of 16 rats. The totals for the Dedicated 7-Day Laboratory are 72 kg (158 lb), 227 dm^3 (8.0 ft^3), and 220 watts. For the Dedicated 30-Day Laboratory, the increase in consumables results in 153 kg (337 lb), 327 dm^3 (11.5 ft^3), and 220 watts. The shared laboratory does not contain monkeys.

3.1.3 ECS CONCEPT FOR PLANTS, INVERTEBRATES, AND CELLS/TISSUES. The requirements for ventilating the plants, invertebrates and cells/tissues are substantially different from those of the vertebrates. The air flow requirements are very low, the quantities of consumables and rates of mass exchange are also very low, and in some cases negligible. The system concept established herein will satisfy the requirements of both the 7- and 30-day missions.

The single ECS loop concept shown in Figure 3-3 supports four cage modules. It includes LiOH for CO_2 removal, a condenser for humidity control, an oxygen resupply bottle, and pumps for air circulation. For the 7- and 30-day missions, silica gel could have been used for dehumdification within the loop. However, the condenser was decided upon, since it will be needed for future longer duration missions.

Table 3-5. Preliminary ECS Weight, Power, and Volume for Two Primate Cages

Item	Weight, kg	Volume, dm^3	Ave. Power, watts
Fixed Hardware for 7 Days:	48	207	210
See Small Vertebrate ECS (2 included)			
Consumables for 7 Days			
Drinking Water	8	in tanks	0
Food	2	in cages	0
LiOH Canister	5	11.2	0
Oxygen + Tankage	9	8.4	10
Total Consumables for 7 Days	24	19.6	10
Totals for 7 Days	72 (158 lb)	226.6 ($8.00 ft^3$)	220
Add-on Fixed Hardware for 30 Days:			
Water Supply Tanks (4)	4	32.0	0
Total Fixed Hardware for 30 Days	52	239.0	220
Consumables for 30 Days			
Drinking Water	33	in tanks	0
Food	9	3.3	0
LiOH Canisters	19	48.0	0
Oxygen + Tankage	40	36.2	0
Total Consumables for 30 Days	101	87.5	0
Totals for 30 Days	153 (337 lb)	326.5 ($11.5 ft^3$)	220

*Food volume shown is that of stored food for 15 days. The volume of food contained in the private cages was assumed to be enough for the first 15 days.

The loop is maintained slightly below cabin atmospheric pressure, so that any leakage will occur into the organism holding units and minimize the possibility of cabin contamination. The leakage that does occur will be vented to the cabin contaminant control system through the pressure control valve. Humidity is controlled in the loop by controlling the coolant flow to the condenser. Individual heaters in the cage modules provide temperature regulation of each module. The relative humidity in each module can be controlled to some extent by controlling the amount of air introduced into the cage module. For example, in the plant module, the plant root ball and media will be moist and may be configured so that evaporation from it will cause the humidity to increase. Thus, the introduction of dry air from the loop can be used to control the humidity to the desired level.

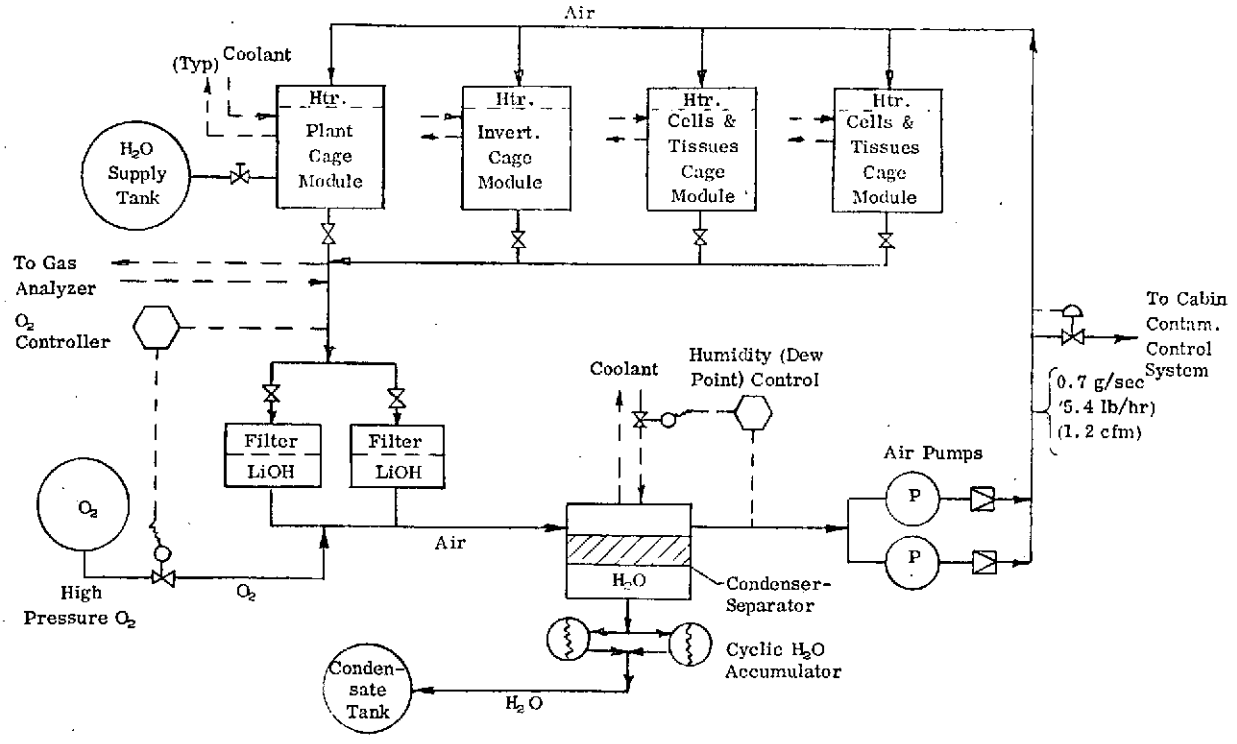


Figure 3-3. ECS Loop Concept for Plants, Invertebrates, and Cells/Tissues

However, the plant cage module flow cannot be excessive, since it is desired to minimize plant perturbations due to air flow past the leaves, stems, etc. A design value of 0.17 g/sec (1.35 lb/hr) or 0.3 cfm at 70°F and 14.7 psia) was chosen. This results in approximately 5 air changes per hour in the plant cage module and an estimated g loading on a typical leaf of less than 10^{-5} g. This same value of 0.17 g/sec was also used for the other three cage modules, resulting in a total loop design flow of 0.7 g/sec (5.4 lb/hr).

The plant cage module contains 140 watts of lighting, and the resulting heat load will probably be rejected to the sortie module liquid coolant. This coolant can be used to control the plant module temperature. When the lights are off, a heater will be used to maintain the cage module at the desired temperature if this temperature is above the ambient cabin temperature. These components, such as lights, heaters, coolant controls, are part of the cage module and have not been included in the list of ECS equipment, which is given in Table 3-6. Similarly in the case of the invertebrate and cells/tissues cage modules, internal heaters, controls, etc., are considered to be part of the cage module. The weight, volume and power of these components are included in the research equipment inventory lists.

Table 3-6. Preliminary ECS Weight, Power, and Volume for Plants, Invertebrates, and Cells/Tissue (All Laboratories)

Item	Weight, kg	Volume, dm^3	Power, watts
Fixed Hardware			
Tubing & Fittings	3	8	0
Valves	2	1.4	0
Condenser/Separator & Control	1	0.5	5
Condensate Accumulator	1	0.5	0
Condensate Collection Tank	1	8	0
Water Supply Tank	1	8	0
Air Pumps (2 included)	9	6	50
Total Fixed Hardware (7 & 30 Days)	18	32.4	55
Consumables (for 7 to 30 Days)			
Water for Plants	7	in tank	0
LiOH + Filters	1	2	0
Oxygen + Tankage + Control	1	1.5	5
Total Consumables	9	3.5	5
Total Fixed Hardware + Consumables (7 - 30 Days)	27 (59.4 lb)	35.9 (1.27 ft^3)	60

The heaters shown in the cage modules are integral with the cage modules. External air heaters in the ECS loop are not used to provide the heat to the cage modules because the low air flow rates are not sufficient to provide the necessary quantity of heat. For example, in a cells and tissues module held at 310°K (37°C), the heat loss to the surrounding cabin was estimated at 50 watts, thermal. This would require an inlet air temperature of 588°K (315°C or 625°F) at the low air flow rate through the cage module, and would result in excessive temperature gradients within the module. In order to maintain uniform temperatures within the module and minimize heat losses, the module heater should be integral with the internal structure of the module.

Another requirement, which is best integrated with the cage modules, is the requirement for bacterial air filtration to prevent cross-contamination between the modules. For this purpose, a millipore filter was assumed to be placed at the air inlet to each module. A radial filter was used to minimise the ΔP.

The list of ECS equipment is shown in Table 3-6. The power estimated for the air pumps was based on an assumed loop pressure drop of 6.9 kN/m^2 (1 psi). The water tanks for vertebrates held 7 kg of water and occupied 8 dm^3 (8 liters). One of the same tanks was used for the plant water needs. The water available for a 30-day mission would be 1.6 dm^3 (1.6 liter) per week. If more water is required, extra tanks could be added.

As mentioned previously, the LiOH and oxygen requirements are practically negligible. The quantities shown in Table 3-6 should readily satisfy the maximum mission requirement of 30 days unless the metabolic values presented in Table 3-1 are much too low.

Table 3-7. Summary of Organism ECS Weight, Volume and Power for the Life Sciences Laboratories

Laboratory	Weight kg	Volume dm^3	Average Power watts
Shared Laboratory (7-Day)			
P, I, C/T	27	36	60
Small Vertebrates	43	118	110
Total	70	154	170
	(151 lb)	(5.44 ft^3)	
Dedicated 7-Day Laboratory			
P, I, C/T	27	36	60
Small Vertebrates	43	118	110
Primates	72	227	220
Total	142	381	390
	(312 lb)	(13.5 ft^3)	
Dedicated 30-Day Laboratory			
P, I, C/T	27	36	60
Small Vertebrates	100	190	110
Primates	153	327	220
Total	280	553	390
	(616 lb)	(19.5 ft^3)	

3.1.4 SUMMARY OF ORGANISM ECS WEIGHT, VOLUME, AND POWER. A summary of the ECS properties for the Life Sciences Laboratories is shown in Table 3-7.

3.2 DATA MANAGEMENT SUBSYSTEM

Data management subsystem (DMS) equipment was estimated for the Life Sciences Laboratories to determine whether the sortie module complement of equipment would adequately support the laboratories. It was generally found that the basic sortie module DMS will support the laboratories with the addition of several tape recorders and video transmission equipment. Further details on the DMS are given below.

3.2.1 SORTIE MODULE DMS. The baseline sortie module contains a DMS to be used by the various FPEs such as Life Sciences, References 4 and 5. A block diagram of the subsystem is shown in Figure 3-4. A mini-computer is provided for experiment control and data processing. The display and control console contains cathode ray tubes, a multifunction display (displays video or symbols), and various control devices. Up to 16 remote acquisition units (RAUs) are located around the laboratory and interface with the subsystems and experiment sensors. Three standard types of tape recorders are available. These are a large volume recorder, a medium capacity recorder, and a special purpose video recorder, the properties of which are given in more detail in Table 3-8. Data acquisition and control signals are transmitted serially throughout the laboratory through a two-wire party-line system. The maximum party-line-system bit rate is 100 kbps. The signals are under the control of the digital control combiner unit (DCCU) according to a predetermined schedule and format, which can be varied, however, by means of the Flexible Format Generator.

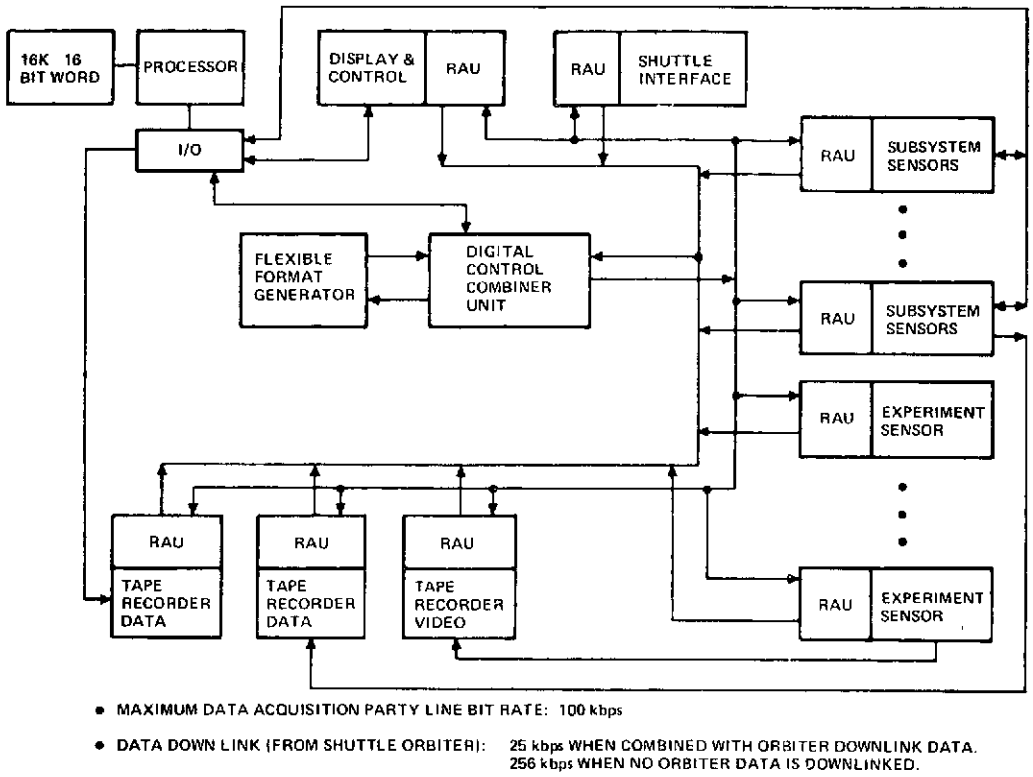


Figure 3-4. Sortie Module Data Management Subsystem Block Diagram

All communications are via the shuttle communications system. The digital data down-link rate, which is provided by the shuttle, varies between 25 and 256 kbps, depending upon whether shuttle orbiter data is being simultaneously down-linked. Wide-band data can also be transmitted. No TV transmission capability is provided as part of the base-line sortie module equipment, and is listed as add-on type equipment in Reference 4 if needed by the FPE using the sortie module.

3.2.2 LIFE SCIENCES LABORATORY SAMPLED DATA MANAGEMENT. In estimating the sampled data requirements of the Life Sciences Laboratories, only research-significant and important housekeeping parameters were included. The laboratory equipment items are generally of a nature that do not affect crew safety unless these items fail catastrophically, nor do they affect the successful return of the shuttle/sortie to earth. Hence, the philosophy behind the requirements for automatic management of data and control of this equipment did not include provisions for complex automatic check-out, failsafe operational redundancy, etc. Instead, the general philosophy was to refrain from unnecessary instrumentation, which will ultimately minimize overall system cost and complexity.

The sampled data requirements for the major data generating equipment items aboard the Dedicated 7-Day Laboratory were estimated and contained in Volume III, Appendix I, of this report.

Table 3-8. Baseline Sortie Module Tape Recorder Characteristics

I.	Large Volume Commercial Tape Recorder Adapted to Space Use		
	Tape Speed:	60 in./sec	
	Tape Width:	1 in.	
	Number of Tracks:	28	
	Packing Density:	20,000 bits/in./track	
	Storage Bit Rate at 60 ips:	1.2 Mbps/track	
	Reel Characteristics:	10-1/2 in. Diameter	14 in. Diameter
	Length:	4600 ft	9200 ft
	Total Data Storage:	31×10^9 bits	62×10^9 bits
	Weight (Commercial Reels):	2.6 kg (5.8 lb)	4.7 kg (10.3 lb)
	Envelope Volume (Storage):	3110 cc (0.11 ft^3)	5100 cc (0.18 ft^3)
	Recorder Weight:	50 kg (110 lb)	
	Recorder Peak Power:	230 watts	
	Recorder Volume:	0.093 m^3 (3.3 ft^3)	
II.	Medium Capacity Tape Recorder		
	Tape Speed:	Up to 60 in./sec	
	Width:	1 in.	
	Number of Tracks:	14	
	Packing Density:	10,000 bits/in./track	
	Real Capacity:	10-1/2 in. dia., 4600 ft, 7.7×10^9 bits (Other reel characteristics same as above)	
	Recorder Weight:	27 kg (60 lb)	
	Recorder Peak Power:	76 watts	
	Recorder Volume:	0.028 m^3 (1 ft^3)	
III.	Video Recorder		
	Tape Speed:	15 in./sec	
	Video Bandwidth:	4.25 MHz	
	Recording Time:	96 min. (nominal 7200 ft)	
	Tape Width:	2 in. (assumed rotary head, 2 in. width tape, 14 in. dia. reel)	
	Reel Weight:	9.1 Kg (20 lb) (estimated)	
	Reel Envelope:	8190 cc (0.30 ft^3)	
	Recorder Weight:	17 kg (37 lb)	
	Recorder Peak Power:	100 watts	
	Recorder Volume:	0.017 m^3 (0.6 ft^3)	

Table 3-9 shows an example of these requirements and the format used in compiling them. For each equipment item, the signals that would be monitored by the DMS are identified along with their pertinent characteristics such as range, resolution, signal type, number of channels, sampling duration, sampling rate, and bit rate information. Referring to the automatic analyzer requirements, an on-off switch monitoring signal is needed to convey this information to the DMS. The DMS was assumed to incorporate time sharing of slots in the overall data acquisition file. Thus, when the automatic analyzer is switched on, the system will allocate a block of data words to be used and tagged for automatic analyzer data. For this reason, the on-off switch status is continuously sampled at the rate of 1 discrete (1 bit) word per second. If two equipment items sharing the same positions within the data acquisition file are turned on simultaneously, a warning will be activated to alert the operator that the system is not ready to accept data from the lower priority equipment. However, the data acquisition file will be designed so that this will not normally happen. While the automatic analyzer is on, the data acquisition system will sample instrumentation that contains information on the specimen identification, time the specimen was taken, the type of analysis being performed, and the measured value (e.g., 8.05 total protein). This data need only be sampled at the rate of once every 10 seconds, since this is much faster than the time required for any single analysis by the automatic analyzer. On the other hand, this sampling rate is very low with respect to the total capability of the sortie data management subsystem. For example, the requirement for the automatic analyzer is 95 kbits per day compared to a total daily capacity of 8.64×10^9 bits/day (at 100 kbps). This represents 0.001 percent of the total capacity, and is based on a 33 min/day interval (sampling duration), during which the automatic analyzer is expected to be on.

A few wide bandwidth signals, such as the audiometer tone signal, are hardwired to the analog handling equipment for direct storage on tape. These signals would result in relatively high digital data rates, and it is not necessary to digitize these signals for processing by the computer.

Table 3-9. Dedicated 7-Day Laboratory Sampled Data Requirements
EU5 — Biochemical and Biophysics Analysis Unit

EQUIPMENT ITEMS (E.U.#/E.I.#) AND SIGNAL IDENTITY	SENSOR/SIGNAL CHARACTERISTICS					PROCESSING				COMMENTS
	Range	Resolution	Signal Type	No. of Chan.	Bits per Sample	Sampling Duration min/day	Sampling Rate per Channel	Total Bit Rate, BPS	Total Bits per Day	
Autoanalyzer (5/7)										
On-Off Control	2 level	1 level	Dis.	1	1	cont.	1/sec	1	86 K	
Specimen/Organism I.D.	1-200	1	Dig.	1	8	33	0.1/sec	1	2 K	
Time of Specimen	0-7 days	1 sec	Dig.	1	20	33	0.1/sec	2	4 K	
Type of Analysis	1-30	1 value	Dig.	1	5	33	0.1/sec	1	1 K	
Measured Value	Variable	0.1%	Dig.	1	10	33	0.1/sec	1	2 K	
General Spectrophotometer (5/11)										
Wavelength Monitor	0-5 V	5 mV	Anal.	1	10	9	500/sec	5000	2.7 M	For maximum scanning rate
Detector Signal	0.5 V	15 mV	Anal.	1	9	9	5000/sec	45 K	24.3 M	For maximum scanning rate
On/Off Control	2 position	1 position	Dis.	1	1	cont.	1/sec	1	86 K	
Output Range Select	1-4	1	Dig.	1	2	9	1/sec	2	1 K	
Scan Speed Select	1-6	1	Dig.	1	3	9	1/sec	3	2 K	
Specimen I.D.	1-100	1	Dig.	1	7	9	0.1/sec	1	negl.	
Auto. Urine Analyzer (5/13) (use E.I. #7)										
Power On/Off	2 positions	1 position	Dis.	1	1	cont.	1/sec	1	86 K	
Specimen/Organism I.D.	1-200	1	Dig.	1	8	75	0.1/sec	1	4 K	
Time of Specimen	0-7 days	1 sec	Dig.	1	20	75	0.1/sec	2	9 K	
Type of Analysis	1-21	1	Dig.	1	5	75	0.1/sec	1	2 K	
Measured Value	Variable	0.1%	Dig.	1	10	75	0.1/sec	1	5 K	
Audiometer (5/16B)										
Tone Signal Output	500-6 KHz	10 Hz	Anal.	1	-	4	-	-	-	Hardwire to analog equipment
Amplifier Gain	5 levels	1 level	Dig.	2	3	4	1/sec	3	1 K	
On-Off Control	2 positions	1 position	Dig.	1	1	cont.	1/sec	1	86 K	
Response Keys	1-12	1	Dig.	1	4	4	1/sec	4	1 K	
Tone Control	0-5 V	0.05 V	Anal.	1	7	4	0.1/sec	1	negl.	
Gas Sampling Commutator (5/50A)										
Gas line being sampled	0-12	1	Dig.	1	4	cont.	1/min	negl.	6 K	
Blood Cell Counter (5/52)										
Power On/Off	2 positions	1 position	Dis.	1	1	cont.	1/sec	1	86 K	
Specimen/Organism I.D.	1-100	1	Dig.	1	7	6	0.1/sec	1	negl.	
Time of Specimen	0-7 days	1 sec	Dig.	1	20	6	0.1/sec	2	1 K	
Type of Analysis	1-7	1	Dig.	1	3	6	0.1/sec	negl.	negl.	
Measured Analysis	Variable	0.1%	Dig.	1	10	6	0.1/sec	1	negl.	

The sampling duration was obtained from the equipment operations model described in Section 6. The total bit rate is the sampling rate per channel multiplied by the product of the number of channels and the number of bits per sample. The total bits per day is the total bit rate multiplied by the sampling duration. The total bits per day, summed for all equipment within the laboratory, were used to calculate an average sampled data rate for the laboratory. Only the Dedicated 7-Day Laboratory sampled data requirements were tabulated for the equipment unit groups. These were used to establish approximate sampled data requirements for the Shared 7-Day Laboratory and the Dedicated 30-Day Laboratory.

The summation of the sampled data requirements for the EU in the Dedicated 7-Day Laboratory is given in Table 3-10. The equipment items generating high data rates are also shown and are potential candidates for special data handling to reduce the load in the DMS if this were later found to be desirable. The table includes (1) the continuous bit rates required for each equipment unit, (2) the bit rates from the high-rate items and the time during which the high rates must be accepted, and (3) the total bits generated per day. The total rate for the Dedicated 7-Day Laboratory is 2580 megabits per day, most of which result from several high-rate equipment items operating continuously. Thus, this total rate could be averaged to yield a meaningful value, which is approximately 30 kbps. This was used as a basis for comparison between the rate required by the Life Sciences Laboratory and that provided by the sortie module. Adding a 50 percent overhead factor to account for scheduling loss and transmission of parity, synchronization, and I.D. information results in a background sampled data rate of 45 kbps.

Table 3-10. Summary of Sampled Data Requirements for the Dedicated 7-Day Laboratory

EU No.	Equipment Unit (EU) & (EI No. and Name)*	EU Sampling Rates: Contin. Data (bps)	EU Sampling Rates: Total Daily Data (Mbits)	High Rate EIs: Sampling Rate (kbps)	High Rate EIs: Sampling Duration (min/day)
1	Visual Records & Microscopy	5	43		
	(150, Biomedical Recorder)			42	17
2	Data Management	14,085	1,313		
	(64, ECG Couplers)			14	cont.
	(64, ECG Couplers)			28	15
	(65, EEG Couplers)			14	5
	(66, EMG Couplers)			21	5
	(143G, Pressure Transducer Couplers)			28	17
	(156, Miscellaneous Couplers)			24.5	21
3	Life Sciences Experiment Support	10,502	958		
	(1A, Accelerometers)			10.5	cont.
	(1A, Accelerometers)			14	60
4	Preparation & Preservation	7	7		
5	Biochemical/Biophysical Analysis	132	67		
	(11, Spectrophotometer)			45	9
6/7	Maintenance & Storage	0	0		
11	Airlock/EVA Capability	3	negl.		
12/31	Biomedical & MSI Support	2	186		
	(65C, Electrophysiology Receiver)			14	177
26	Radiobiology Support	1	negl.		
40/41/42	Vertebrate Holding & Support	16	3		
50/51/70	Plant Holding & Support/ Invertebrates	18	1		
60/61	Cells/Tissues	7	1		
80	LSS Test Unit	23	2		
91/93	MSI Measurements & Mobility	1	2		
	Subtotals	24,802	2,583		
	Approximate Average Bit Rate	≈ 30 kbps			
	50% Overhead Factor	15 kbps			
	Average Background Data Rate	45 kbps			
	EI 11, Spectrophotometer Rate	45 kbps			
	Maximum Sampled Data Rate	90 kbps			

*Of equipment items (EIs) requiring a high sampling rate.

Superimposed upon this background rate will be short periods of high-rate data transmission when the high-rate devices shown in Table 3-10 are being used. This data is all of relatively short duration and can be scheduled not to occur simultaneously. The highest rate identified is 45 kbps from the spectrophotometer, which is on an average of 9 minutes per day. Adding this value to the background rate yields a maximum instantaneous laboratory rate of 90 kbps.

This rate is below the 100 kbps sortie capability and could be further reduced, if required, by hardwire connections of several equipment items to the recorders.

It may be noted that a large contribution to the total data rate results from the accelerometers in EU3 and the ECG couplers in EU2, Table 3-10. If later analysis indicates the desirability of reducing the Dedicated 7-Day Laboratory requirements, this data could be processed independently. This would drastically reduce the average data rate requirements of the laboratory. However, since the inclusion of the accelerometers and ECG data does not impose an overload on the sortie DMS at this time, it was conservatively left in the total tabulation.

The recording of all laboratory sampled data in pulse code modulated (PCM) form was assumed to be required to permit subsequent ground analyses. A study of the data rates, recording durations, and recorders available aboard the sortie module was performed to determine the recorder and magnetic recording tape requirements. It was found that the Shared 7-Day Laboratory requirement for PCM as well as analog data recording could be satisfied by a single medium-capacity recorder (see Table 3-8) and eleven 10-1/2-inch-diameter reels of tape. This was based on continuous recorder operation at 7-1/2 ips, and the use of one track at a time for the serial recording of PCM data. A second track was allocated to the continuous recording at various intermittent analog signals.

For the Dedicated 7-Day Laboratory, the data rates are slightly higher and require two medium-capacity recorders for PCM and analog data. The second recorder is needed to provide continuous recording during the 12-hour period during which no payload specialists are in the laboratory. The number of reels of tape necessary for this case is 26.

For the Dedicated 30-Day Laboratory, PCM and analog data can be recorded using the two medium-capacity recorders, as in the Dedicated 7-Day Laboratory, but 120 reels of 10-1/2-inch-diameter tape would be required. This would weigh 316 kg and occupy 0.37 m^3. Therefore, an alternate approach was used, adding a large-volume recorder with four times more data storage density capacity than the medium-capacity recorder; see Table 3-10. A full tradeoff and gain was not conducted due to a lack of data on cost penalties and other factors; however, a preliminary weight tradeoff is shown below to favor the use of the larger recorder. This large volume recorder requires only 13 reels of 14-inch-diameter tape weighing 61 kg and occupying 0.07 m^3. The medium-capacity recorder was also left on the Dedicated 30-Day Laboratory for miscellaneous use on an as-needed basis.

Items Required for 30-Day Mission	Weight of Items (kg)	
	Medium Capacity Recorder (2 Reqd)	Large-Volume Recorder
Recorder	54	50
Tape	316	61
Fuel (H_2O_2) for Electric Power*	24 (for 76 W)	71 (for 230 W)
Prorated Tankage for Fuel*	12	38
Total Weight for Comparison	406	220

*Fuel and tankage penalties were based on guideline values given in NASA Reference 4.

Transmission of all data from the sortie module is provided by the shuttle orbiter

communications subsystem. In comparing the Life Sciences requirements to the shuttle capability, it was assumed that 10 percent of the sampled data acquired and processed would require transmission to ground for analysis by the principle investigators. Ten percent of the average bit rate is 4.5 kbps. Assuming a worst-case orbit altitude of 100 n.mi., the percent of contact time with 7 manned space flight network (MSFN) stations is 8.9 percent, Reference 5. Using this percentage and 4.5 kbps continuous data rate results in a down link data rate of 50 kbps compared to 25-256 kbps available from the shuttle communications system. At an altitude of 270 n.mi., the percent of contact time is 29 percent, and the resulting data rate required is 16 kbps, which is within the shuttle minimum capability of 25 kbps. The altitude of the Life Sciences Laboratory has not been determined and probably will be predicated upon many factors in addition to communications requirements. However, the communications requirements would favor the higher altitudes if the minimum down-link capability of 25 kbps were imposed upon the Life Sciences Laboratories. This would appear unlikely in view of the range capability of up to 256 kbps. It was assumed that suitable recorder and playback equipment would be available aboard the shuttle orbiter for recording a continuous data stream and then playing this back during the MSFN contact and transmission to ground. Hence, no added equipment was placed aboard the sortie module for this purpose.

3.2.3 LIFE SCIENCES LABORATORY VIDEO DATA MANAGEMENT. The Life Sciences Laboratories will generate a large amount of video data, which will require a large DMS recording capability. In order to estimate this capability, while maintaining a facility approach to the laboratory definitions, an analytical model representing the video data acquisition was formulated. It was based upon the stated desires of the scientific investigators involved in the Task A and B effort of the preceding contract and is discussed below.

Three general types of scheduling for video data acquisition were identified and used as the basis of the requirements. These include (1) single picture frames taken at several second intervals on a continuous basis, (2) short duration vidicon operation at scheduled intervals of several minutes, and (3) longer duration camera operation to record specific experiment events at random times. The analytical model of overall video data acquisition scheduling was determined using the above three types of scheduling and the characteristics of the laboratory equipment and functional requirements. The first type of scheduling given above is used to obtain time-lapse pictures of plant and animal movement. The plant pictures can later be viewed at a higher rate to speed up plant movement for study, and the animal pictures may be used to determine patterns of animal activity.

In both dedicated laboratories, eight cameras are devoted mainly to such time-lapse picture taking. Two of these cameras were assumed to be high resolution cameras with 0.64×10^6 picture elements (pixels) per frame (800 lines) and 7 bits per pixel. These were for plant and invertebrate pictures. For vertebrate time-lapse pictures, standard video cameras were assumed with 0.276×10^6 pixels/frame (525 lines) and 4 bits per pixel. One of these cameras is required in each of the two vertebrate cage modules, and two were assumed to be required for complete visual coverage of each of the two primate cylinders. This results in 6 standard cameras for the vertebrates.

The cameras in the cage modules are moved from one rat cage to the next by a translating servomechanism device similar to that used on an x-y plotter. Each of the eight cameras for time-lapse pictures was assumed to take one frame every ten seconds continuously for 24 hours per day. This is conservative, since there will be periods when no time-lapse pictures will be taken, such as when the vertebrate cages are in darkness. However, the various cameras will be nonoperative at different times, making it difficult to take advantage of these periods to save on data recording equipment and tape. Therefore, full 24 hour data acquisiton was assumed.

For the shared laboratory without the primates, only the small vertebrate, plant, and invertebrate cameras are required. This reduces the number of cameras for time-lapse use from 8 to 4. Two of the four were assumed to be high resolution cameras and two were assumed to be standard resolution. As in the dedicated laboratories, one picture per camera every 10 seconds on a 24-hour continuous basis was used.

The second type of scheduling can be characterized by considering MSI habitability studies. These studies are intended to determine patterns and trends in crew behavior in both the shuttle and the sortie module, and are required only for the 30-day dedicated laboratory. For this type of data, 4 cameras were used and each camera was operated for 10 seconds every 15 minutes. Hence, every 15 minutes the location and activity of each crewman could be assessed. Standard resolution cameras are used for this purpose.

The third class of video data is for recording visual aspects of specific experiment phenomena or procedures. Examples would include pictures of a crewman acting as a subject during rotating litter chair experiments, and specific biological procedures such as dissection of an organism. It was assumed that a total of 120 minutes per day of video coverage would satisfy this requirement for the dedicated laboratories. This was estimated from the following breakdown:

Biomedical/MSI/LSS Experiments (2 Cameras)	30 min/day
Small Vertebrate Experiment Events and Procedures (2 Cameras)	30 min/day
Primate Response to Stimuli and Monitoring (4 Cameras)	60 min/day

A total of 60 minutes/day was used for the shared laboratory, since no primates are included in this payload. Two standard resolution cameras were assumed for the biomedical/MSI/LSPS video. The other event monitoring was assumed to use the same cameras that are used for the time-lapse data described above. The total number of video cameras for the Life Sciences Laboratories is summarized on the following page.

The time lapse video data will be digitized and recorded on tape at a much lower rate than that normally required for live video. Standard video operates at 30 frames/sec, whereas each time-lapse camera takes one frame every 10 seconds, a factor of 300 times

Camera Use	Major Mode of Camera Operation	Number of Cameras		
		Shared 7-Day Lab	Dedicated 7-Day Lab	Dedicated 30-Day Lab
Biomed/MSI/LSS Events	Event Monitoring	2	2	2
Habitability Studies	Short Duration	0	0	4
Small Vertebrates	Time Lapse	2	2	2
Plants & Invertebrates	Time Lapse	2	2	2
Primate Coverage	Time Lapse	0	4	4
	Total	6	10	14

slower. Through an analysis of the bit rates from the two high-resolution and 6 standard-resolution time-lapse cameras aboard the dedicated laboratories, it was determined that their data could be stored using two tracks at a time of the large volume tape recorder included in Table 3-8. This recorder, running at 60 ips, will take 7.2 hours to fill a 14-inch-diameter reel of tape (28 tracks total). However, since the crew will be out of the laboratory for up to 12 hours, and time-lapse data recording may have to continue during this 12-hour period, two recorders were included. The number of 14-inch reels required for continuous coverage of the time-lapse video data aboard the dedicated laboratories is 22 for 6.5 days, and 101 for 30 days. This is somewhat conservative, since data will not be generated continuously. Future studies where more specific requirements are known may be able to reduce the number of reels required and possibly the number of recorders. The number of reels could also be reduced through more sophisticated processing and compression of the data. However, this would be more costly and might not be warranted in cases where the shuttle payload weight capacity is higher than that required for the Life Sciences Laboratory being launched.

For the shared laboratory only 4 time-lapse cameras are being used, and their output, recorded serially, will fit onto a single track of the large-volume recorder. Thus, only one recorder is required. Each reel will last about 14.4 hours, which results in 11 reels required for 6.5 days.

Both the short duration and event monitoring video data will be recorded on video recorders; see Table 3-8. Although no two events were assumed to occur simultaneously, two cameras may sometimes be necessary to cover the field of view in which a single event is occurring. An example would be the two cameras required to cover the complete internal volume at the primate cylinders. For this reason, two recorders were included in the dedicated laboratories to record simultaneously the output of two video cameras, whereas only one recorder was used in the shared laboratory, which does not contain primates. These recorders will be turned on only when video data is to be recorded.

Item	Weight kg (lb)	Power (Watts)	Volume m^3 (ft^3)
TV Receiver	4.5 (10)	15	0.006 (0.2)
TV Transmitter	13.6 (30)	100	0.014 (0.5)
Antennas	11.4 (25)	0	0

Reference 4 stated that payload video transmission to ground could not be provided by the shuttle communications systems and if necessary would have to be provided as part of the laboratory equipment. The reference also gave the weight, power, and volume of the TV communications equipment shown at left.

This equipment was added to the data management equipment aboard all laboratories for the purpose of downlinking the event-monitoring TV. It was assumed that the time-lapse TV as well as the habitability data would not require ground observation until after return to earth. At 100 n.mi., the single transmitter can downlink TV data for about 2 hours, which should be sufficient to transmit the required video data.

3.2.4 SUMMARY OF DATA MANAGEMENT SUBSYSTEM. In summary, the sortie module DMS will satisfy the requirements of the Life Sciences payloads with the addition of several recorders and some TV communications equipment.

A summary of the recorders required aboard all the laboratories is shown in Table 3-11 and compared to the number of recorders aboard the baseline sortie module. The reasons for the extra recorders have been discussed previously.

Table 3-11. Tape Recorders Required for the Life Sciences Laboratories

Recorder	Shared 7-Day Laboratory			Dedicated 7-Day Laboratory			Dedicated 30-Day Laboratory		
	Large Cap.	Med. Cap.	Video	Large Cap.	Med. Cap.	Video	Large Cap.	Med. Cap.	Video
Number in Sortie Module DMS	1	1	1	1	1	1	1	1	1
Total Number Required									
Time-Lapse Video	1			2			2		
PCM & Analog Data		1			2		1	1	
Real-Time Video			1			2			2
Subtotal	1	1	1	2	2	2	3	1	2
Extra Required for Life Sciences Laboratory	0	0	0	1	1	1	2	0	1

The DMS fixed equipment is summarized in Table 3-12, which indicates both the existing sortie module equipment and that additionally required for Life Sciences. Referring to the table, the sortie module baseline data management equipment includes a small computer, input/output device, digital control combiner unit, flexible format generator, 10 remote acquisition units, 3 interface units, and the three tape recorders; see Figure 3-4. This equipment, in addition to the control and display equipment, is the same for all three laboratories. As may be noted, however, the power consumed is slightly different for each laboratory. The main reason for this is the different modes of operation required for the tape recorders, as discussed previously. For example, the large-volume recorder aboard the shared laboratory is run continuously to record time-lapse video data. However, aboard the dedicated laboratories, two such recorders are used for the time-lapse coverage, each running only one-half the time. Thus, the average power required for the single large-volume recorder aboard these laboratories is less than for the shared laboratory.

The additional equipment includes identical TV communications hardware for each laboratory, and tape recorders for the dedicated laboratories. The total weight, power, and volume for this additional equipment is that which was considered chargeable to the Life Sciences Laboratories specifically. Thus, these values are carried into the total tabulations in subsequent sections of this report that characterize the Life Sciences payload.

The weight and volume of magnetic tape required for the Life Sciences Laboratories is given in Table 3-13 and is quite large, especially for the Dedicated 30-Day Laboratory.

Table 3-12. Data Management Subsystem Weight, Power, and Volume Summary

Item	Shared 7-Day Lab			Dedicated 7-Day Lab			Dedicated 30-Day Lab		
	kg (lbs)	dm^3 (ft^3)	watts*	kg (lbs)	dm^3 (ft^3)	watts*	kg (lbs)	dm^3 (ft^3)	watts*
Sortie Module Baseline Data Management Equipment	148 (326)	187 (6.6)	418 (410)	148 (326)	187 (6.6)	274 (257)	148 (326)	187 (6.6)	392 (338)
Sortie Module Control & Display Equipment	139 (306)	340 (12)	540 (0)	139 (306)	340 (12)	540 (0)	139 (306)	340 (12)	540 (0)
Existing Sortie Module Equipment Subtotals	287 (631)	527 (18.6)	958 (410)	287 (631)	527 (18.6)	814 (257)	287 (631)	527 (18.6)	932 (338)
Sortie Module Add-On TV Communications Equip.	30 (66)	20 (0.7)	29 (29)	30 (66)	20 (0.7)	29 (29)	30 (66)	20 (0.7)	29 (29)
Additional Tape Recorders	0	0	0	94 (207)	139 (4.9)	170 (153)	117 (257)	204 (7.2)	250 (234)
Additional Equipment Subtotals (Chargeable to the Life Sciences Laboratories)	30 (66)	20 (0.7)	29 (29)	124 (273)	159 (5.6)	199 (182)	147 (323)	224 (7.9)	279 (263)
Total DMS Fixed Equipment	317 (697)	547 (19.3)	987 (439)	411 (904)	686 (24.2)	1013 (439)	434 (955)	751 (26.5)	1211 (601)

*Average power values are given. In this column, the 12-hour on-duty average is the upper number, and the 12-hour off-duty power is the lower value in parentheses.

Table 3-13. Estimated Magnetic Recording Tape Requirements for the Life Sciences Laboratories (Based on Data in Table 3-8)

Data Recorded	Shared Laboratory			Dedicated 7-Day Laboratory			Dedicated 30-Day Laboratory		
	No. of Reels and Dia.	Wt, kg (lb)	Vol, dm^3 (ft^3)	No. of Reels and Dia.	Wt, kg (lb)	Vol, dm^3 (ft^3)	No. of Reels and Dia.	Wt, kg (lb)	Vol, dm^3 (ft^3)
Sampled & Analog (Not TV) Data (1 inch width)	13 ($10\frac{1}{2}$")	35 (77)	41 (1.45)	26 ($10\frac{1}{2}$")	69 (152)	81 (2.86)	13 (14")	61 (134)	66 (2.33)
Video Time Lapse Data (1 inch width)	13 (14")	61 (134)	66 (2.33)	26 (14")	122 (268)	133 (4.70)	120 (14")	562 (1236)	612 (21.6)
Video Real Time Data (2 inch width)	5 (14")	45 (99)	42 (1.48)	9 (14")	82 (180)	76 (2.69)	53 (14")	482 (1060)	450 (15.9)
Total		141 (310)	149 (5.27)		273 (600)	290 (10.2)		1150 (2431)	1128 (39.9)

The large quantities are due to the video recording requirements and may be conservative, depending upon the validity of the video data acquisition model described earlier in this section. The large quantity of tape required for time-lapse data could be reduced by increasing the time between frames to more than 10 seconds, or by taking video pictures on a scheduled but discontinuous basis rather than 24 hours per day. For example, a duty cycle of 12 hours per day and one picture every 20 seconds would reduce the tape requirements to about one-quarter of the quantity shown in Table 3-13 (actually less than one-quarter, since a step reduction in recorder speed could be realized, which affects tape requirements in a nonlinear way).

The real time video also requires a large quantity of tape, based on the assumption of 2 hours of video data per day. Possible ways to reduce this quantity include (1) downlinking of data in such a way that tape could be re-used, (2) use of advanced recording hardware, which may permit greater data packing densities, (3) reduction in video data recording requirements.

As implied in the preceding paragraphs, the tape requirements can be reduced through review and reduction of requirements. However, the requirements used here were consistent with the "first-cut" desires of the scientists consulted throughout the Life Sciences payload definition program. At the time that the tape requirements were evaluated, the 30-day laboratory weight was well under the available guideline shuttle launch weight capability, and a philosophy of least expense led to the acceptance of the large quantity of tape. Currently, a lower shuttle weight capability guideline has resulted in a total laboratory overweight condition for the Dedicated 30-Day Laboratory. Thus, the reduction of recording tape is one area in which the overweight condition could be partially alleviated, through alternative data processing techniques or reduction of the video requirements.

3.3 ELECTRICAL POWER SUBSYSTEM

The sortie module carries two, 5 kW, H2-O2 fuel cells for a total power capability of 10 kW. Of this, 4-5 kW average power is allocated for FPE experiments with 7 kW available for peak loading periods, Reference 6. The sortie module, however, carries only enough fuel to provide experiments with 150 kW-hr of total energy. This amounts to 0.96 kW average power consumption over 6-1/2 days of on-orbit experiment time, corresponding to a nominal 7-day shuttle flight. The Life Sciences Laboratories exceed this value and therefore require additional fuel, which is chargeable to the laboratories.

Table 3-14 summarizes the electrical power requirements imposed upon the sortie module for each of the three Life Sciences Laboratories. The upper part shows the power and energy usage of the laboratories, and the lower part indicates the additional fuel and tankage required to meet these usage requirements.

Table 3-14. Electrical Power System Requirements for the Life Sciences Laboratories

	Shared	Dedicated Laboratories	
	7-Day Lab	7-Day	30-Day
Average Power Usage			
Research Equipment (kW)	1.13	1.59±	1.90
Organism EC/LSS & DMS (kW)	0.20	0.59	0.67
Total	1.33	0.59	2.57
Total Energy Consumption (kW-hr)	208	340	1850
Total Energy Available on Sortie Module (kW-hr)	75 *	150	150
Extra Energy Required (kW-hr)	133	190	1700
Extra Fuel (H_2 & O_2) Required (kg)	58	82	729
Extra Tanks Required (Apollo Tanks):			
For H_2			
Number	1	1	7
Tank + H_2 Weight (kg)	39	43	311
Tank Envelope Volume (m^3)	0.44	0.44	3.09
For O_2			
Number	1	1	6
Tank + O_2 Weight (kg)	91	112	844
Tank Envelope Volume (m^3)	0.34	0.34	1.70
Total Tankage & Fluid Weight - kg (lb)	130 (286)	155 (341)	1155(2540)

*Assumed

Average power usage is broken down into that required for the research equipment and that required for the organism ECS and DMS subsystems. The values for the research equipment were obtained from the equipment unit data packages in Volume III, Appendix I, and averages between total on-duty and off-duty power requirements. The subsystem power values have been presented in the two preceding sections, and are also averages of on-duty and off-duty power. The total average power requirements range from 1.33 to 2.57 kW and are well under the average sortie module fuel cell capability of 4-5 kW; however, the requirements exceed the average power capability corresponding

to the standard quantity of fuel carried. Converting the laboratory average power requirements to energy, and using 6-1/2 days on-orbit time for the 7-day missions, results in a range of 208 to 1850 kW-hr for comparison to the 150 kW-hr energy available. The difference between these requirements and the sortie module energy provided is indicated in the table. For the Shared 7-Day Laboratory, only one-half of the 150 kW-hr has been assumed to be available for Life Sciences research. the remaining being used by the sharing FPE.

The properties of the Apollo supercritical storage tanks are shown in the accompanying table. The weight of fuel required was calculated based on 0.045 kg/kW-hr (0.1 lb/kW-hr) of H_2 and 0.364 kg/kW-hr (0.8 lb/kW-hr) of O_2 plus 5% allowance for residuals. One extra O_2 and one extra H_2 tank are required for the 7-day missions. Seven H_2 tanks and five O_2 tanks are required for the 30-day mission. The tankage envelope volumes are also shown in the table, and were assumed to be placed outside the sortie module.

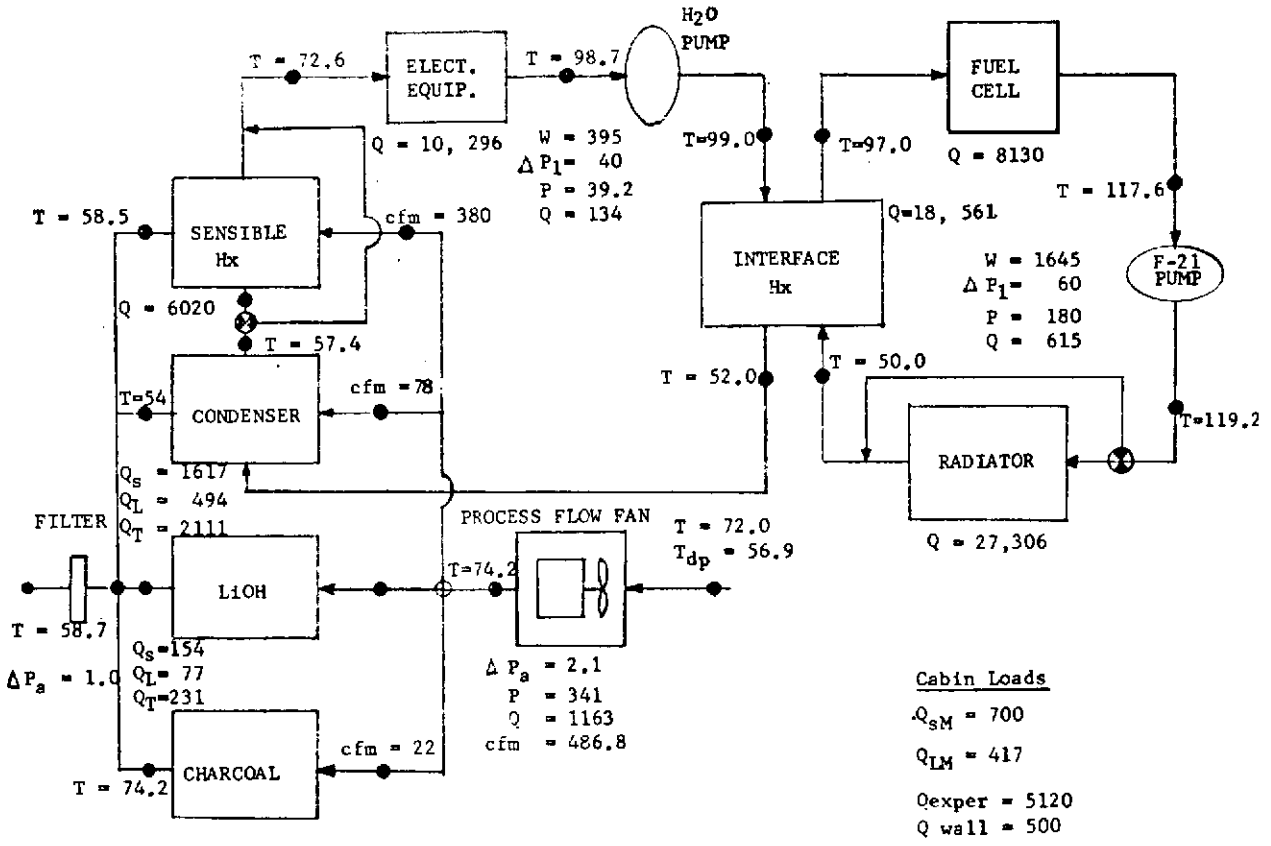
	H_2 Tank		O_2 Tank	
Tank Dry Weight, kg	33		39	
Usable Fluid Weight, kg	13		145	
Operating Pressure, kN/m^2 (psia)	1720	(250)	6380	(925)
Inside Diameter, cm (in.)	71.7	(28.2)	63.7	(25.1)
Girth Support Ring Diameter, cm (in.)	83.3	(32.8)	71.7	(28.3)
Tank Height, cm (in.)	81.0	(31.9)	84.3	(33.2)
Cylindrical Envelope Volume, dm^3 (ft^3)	442	(15.6)	340	(12.0)

3.4 THERMAL CONTROL SUBSYSTEM

During the course of this Life Sciences Payload Definition Study, there was an alteration in the NASA guidelines on the sortie module characteristics. As part of the initial guidelines, a detailed flow schematic of the thermal control subsystem (TCS) was included and had the capacity to reject approximately 1.5 kW_t of experiment heat load. Since the Life Sciences Laboratories generated more heat than this amount, the extra heat rejection equipment was determined and planned to be charged to the laboratories. Later in the study, however, Reference 6 specified that the sortie module should be capable of rejecting 4-5 kW_t corresponding to the average electrical power capability. This reference was a requirements document, and no details of the TCS were given. The 4-5 kW_t specification was stated as a sortie module design goal.

Based upon these final heat rejection values of 4-5 kW_t, extra heat rejection equipment does not need to be added to the sortie module, since the Life Sciences heat loads do not exceed this range. However, since no details of this larger capacity TCS are available, the integration of the Life Sciences load and the sortie module TCS could not be evaluated. For this reason, several pertinent integration aspects of the earlier system, where the extra equipment was needed, are presented below. It should be remembered, however, that the final Life Sciences Laboratories do not include any add-on equipment or consumables for heat rejection equipment.

As presented in Reference 4, the thermal control subsystem (TCS) was part of the sortie module environmental control subsystem, and is shown schematically in Figure 3-5. The TCS heat rejection space radiators rejected a total of 8 kW_t (27,300 Btu/hr) to space. Of this load, 2.38 kW_t (8130 Btu/hr) was picked up by the freon-21 from the



Legend

T	=	Temp (°F)
T_{dp}	=	Dewpoint (°F)
Q	=	Heat Load (Btu/hr)
W	=	Flow Rate (lb/hr)
cfm	=	ft^3/min
P	=	Power (watts)
ΔP_a	=	Air Pressure Change (inches H_2O)
ΔP_l	=	Liquid Pressure Change (psi)

Subscripts

S	=	Sensible
L	=	Latent
T	=	Total
M	=	Metabolic (CREW)

Figure 3-5. Sortie Module TCS Flow Schematic (English Units)

fuel cell and 5.44 kW_t (18,560 Btu/hr) was picked up from the interface heat exchanger, as shown in Figure 3-5. The interface heat exchanger transferred heat from the water coolant within the module to the freon-21 coolant used in the external radiator loop. The internal heat loads included 2.24 kW_t (7640 Btu/hr) sensible load to the cabin air, 0.14 kW_t (490 Btu/hr) latent load to the cabin air, and 3.02 kW_t (10,300 Btu/hr) to the

water from cold plated equipment. Of these loads, 1.50 kW_t (5120 Btu/hr) cooling was to be available for cooling experiment loads. These loads could be cooled by water at from 296-310°K (73-99°F) or by cabin air.

The heat rejection requirements of the Life Sciences payload are summarized in Table 3-15. The electrical load was derived by assuming that all the electrical power required by the payload will appear as heat internal to the sortie module. The metabolic load results from the vertebrates in each payload. The shared laboratory metabolic load is smaller than the dedicated laboratory load because of the absence of the two monkeys.

Table 3-15. Summary of Life Sciences Heat Loads

Item	Shared 7-Day Lab	Dedicated 7-Day Lab	Dedicated 30-Day Lab
Life Sciences Laboratory Heat Loads			
Electrical Equipment, kW	1.33	2.18	2.57
Organism Metabolic Loads, kW_t	0.04	0.10	0.10
TOTALS	1.37	2.28	2.67
Sortie Module Heat Rejection Capability (Final Guideline), kW_t	2-2.5 (1/2 assumed)	4-5	4-5
Extra Heat Rejection Equipment Required	None	None	None
Example of Extra Heat Rejection Equipment in the Case of a Sortie Module Heat Rejection Capability Deficiency			
Sortie Module Heat Rejection Capability, kW_t	0.75	1.5	1.5
Deficiency, kW_t	0.62	0.78	1.16
Water Required to Reject Extra Heat, kg	165	208	1425
Tankage: Weight, kg	17	21	143
Volume, dm^3	198	250	1710
One kw Capacity Water Boiler: Weight, kg	13	13	13
Volume, dm^3	28	28	28
Total Water & Hardware for Extra Heat Rejection			
Weight, kg	195	242	1581
Volume, dm^3	226	278	1738
(ft^3)	(8.0)	(9.8)	(61.4)

As shown in the table, the laboratory requirements exceeded the sortie module capability by up to approximately 1 kW_t. In the case of the shared laboratory, the sharing payload was assumed to require one-half of the available heat rejection capability with the remaining 0.75 kW_t available for the Life Sciences Laboratories. To provide for the extra heat rejection, a water boiler (or sublimator) was assumed. It is stated in Reference 4 that, "A water boiler may also be required [in addition to the radiator] on certain missions," indicating that this solution to extra heat load problems was being contemplated for the sortie module.

Table 3-15 shows the weight of the water required for the boiler, including a 10 percent contingency for water carry-over losses. Allowances of 10 percent and 20 percent are also included for tankage weight and envelope volume respectively. A 1-kW_t water boiler and associated hardware was estimated to weigh 13 kg and occupy 28 dm^3. This boiler was used for all three laboratories. The resulting total weight and volumes are shown in the table. It was expected that all the water and tankage would be located outside the sortie module. The water boiler would probably be located inside, since it was assumed to directly interface with the internal water loop of the environmental control subsystem (rather than with the freon-21 external loop). It would be connected to a line to space vacuum for water vapor venting. The recommended placement of such a water boiler in the environmental control loop is shown in Figure 3-6. This possible configuration shows the location of the extra cooling load to provide the low temperature coolant in the organism ECS for dehumidification. This dehumidification load is approximately equal to the extra heat load required for the Life Sciences payload. If located as shown, it will provide the low temperature cooling without raising the temperature to the cabin condenser. During certain operating conditions, this temperature will drop below 284°K (52°F), which will not be detrimental to the function of the cabin condenser, assuming that an adequate humidity controller is provided.

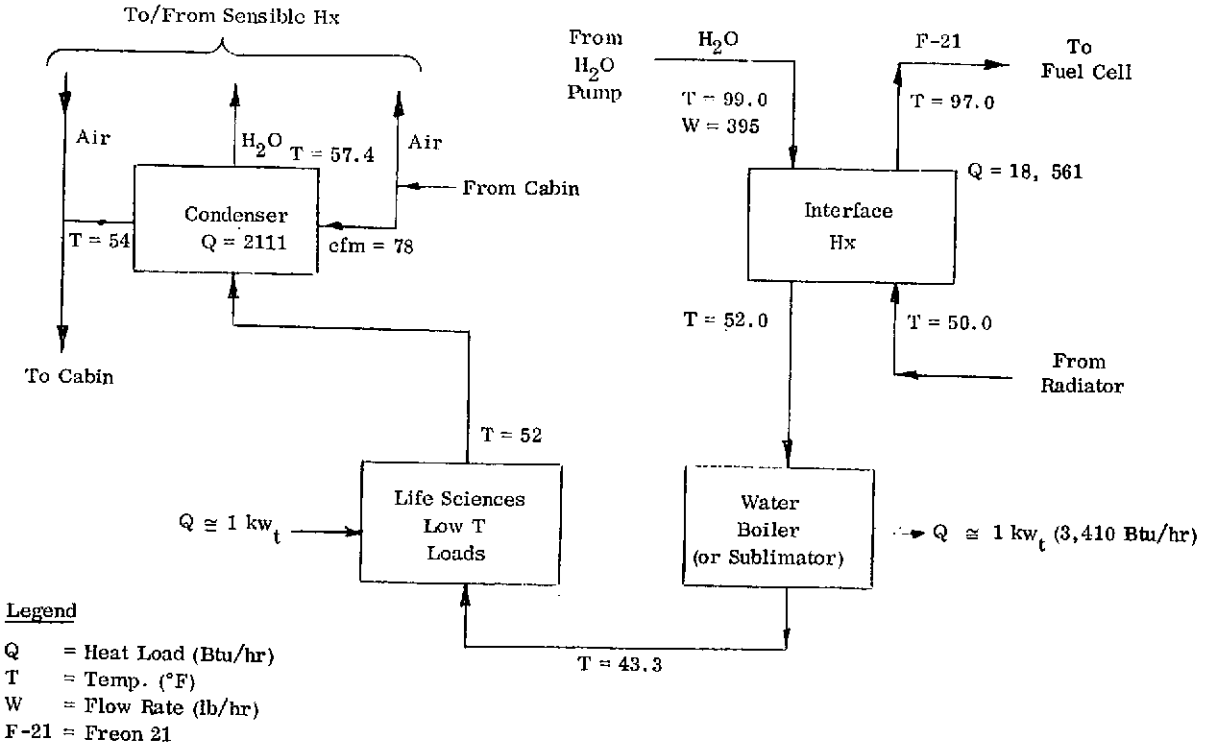


Figure 3-6. Potential Location of Water Boiler in Sortie Module TCS (Engish Units)

The lower temperature coolant resulting from the use of the water boiler could actually be of assistance in providing lower temperature cooling to loads other than the organism ECS if required. These other research equipment loads have not been analyzed in detail, but may require a lower temperature coolant than the 296-310°K (73-99°F) provided by the sortie thermal control equipment.

3.5 CREW EC/LSS SUBSYSTEM

The baseline shuttle orbiter/sortie module provides crew EC/LSS equipment and consumables for the two shuttle crewmen plus two payload specialist for seven days. Any additional payload specialists or any extension in mission duration beyond seven days is chargeable to the payload.

Table 3-16. Crew EC/LSS Equipment Required to Support the Life Sciences Laboratories

Equipment	Weight, kg (lb)	
	Dedicated 7-Day Laboratory	Dedicated 30-Day Laboratory
Fixed Equipment for One Extra Man		
Seats and Restraints	54	
Personal Equipment	14	
Emergency Equipment	24	
Weight of Crewman	162	
Miscellaneous	28	
Fixed Equipment Subtotal	282 (620)	
Consumables	Basis	
	2 Men, 7 Days (14 m-d)	2 Men, 30 Days + 4 Men, 23 Days (152 m-d)
Oxygen + LiOH Canisters	36	405
Food	18	187
Utensils	8	98
Clothing	8	75
Consumable Subtotal	70 (154)	765 (1680)
Total Fixed Equipment + Consumables	352 (774)	1047 (2300)

In the case of the Life Sciences Laboratories, the Shared 7-Day Laboratory requires only one payload specialist and therefore no extra equipment. However, the Dedicated 7-Day and 30-Day Laboratories do require extra equipment. For these laboratories, three payload specialists are required, and additional fixed equipment for the extra man is chargeable to the Life Sciences Laboratories. Also, since the shuttle provides consumables only for two payload specialists for seven days, additional consumables are chargeable to the Life Sciences Laboratories. For the Dedicated 7-Day Laboratory, the quantity corresponds to seven man-days of occupancy, and for the Dedicated 30-Day Laboratory, the quantity corresponds to an additional five men for 23 days. The weight of the fixed equipment and consumables is given in Table 3-16.

3.6 SUMMARY OF SUPPORTING SUBSYSTEM WEIGHT, POWER, AND VOLUME

Table 3-17 is a summary of the weight, power, and volume of the extra subsystem requirements necessary to support the Life Sciences Laboratories (in addition to the sortie module and shuttle baseline subsystems). The subsystems listed in the table have been discussed in the preceding sections. All subsystems will require extra equipment except the TCS. The largest weight requirements are for the 30-day mission for the DMS recording tape, fuel for the EPS, and consumables for the crew EC/LSS. The average power requirements of the extra subsystem equipment are quite low. An allowance of 10 percent was added to all subsystem weights and volumes to account for supporting structure.

Table 3-17. Summary of Supporting Subsystem Weight, Power, and Volume

Subsystems and Supporting Equipment	Shared 7-Day Laboratory			Dedicated 7-Day Laboratory			Dedicated 30-Day Laboratory		
	Wt (kg)	Avg Power (W)	Vol (dm^3)	Wt (kg)	Avg Power (W)	Vol (dm^3)	Wt (kg)	Avg Power (W)	Vol (kg)
Organism ECS	70	170	154	142	390	381	280	390	553
DMS Hardware & Tape	171	29	169	397	199	449	1252	279	1352
EPS Fuel & Tankage	130	0	0*	155	0	0*	1155	0	0*
Thermal Control	0	0	0	0	0	0	0	0	0
Crew EC/LSS Equipment	0	0	0	352	TBD	0*	1047	TBD	0*
Supporting Structure (10%) of Subsystem Equipment	37	0	32	105	0	83	373	0	191
Total	408	199	355 (12.5 ft^3)	1151	589	913 (32.3 ft^3)	4107	669	2096 (74.1 ft^3)

*Assumed to be outside the sortie module.

SECTION 4

SORTIE MODULE/LIFE SCIENCES LABORATORY LAYOUTS AND SUMMARY

4.1 LIFE SCIENCES LABORATORY LAYOUTS

Having established the properties of both the research and supporting subsystem equipment for the Life Sciences Laboratories, preliminary layouts were developed for each laboratory. These layouts were based on the sortie module configuration and the description contained in References 4 and 5. This configuration contains a single floor running longitudinally in a 4.76m (14 ft) diameter by 7.32m (24 ft) long sortie module.

The Shared 7-Day Laboratory layout is shown in Figure 4-1. The Life Sciences equipment is generally located in the right end of the sortie module above the single floor (as drawn in Figure 4-1). The Life Sciences equipment occupies approximately one-half the length of the sortie module above the floor. The resulting envelope volume is approximately 31.8 m^3 (1300 ft^3). In the left end of the module and also below the floor, is subsystem equipment standard to all sortie modules. This equipment includes the DMS crew station console and electronics, crew systems equipment, crew EC/CSS equipment, and EPS equipment. The total internal volume of the sortie module is approximately 87.8 m^3 (3100 ft^3). Subtracting the 31.8 m^3 envelope volume of the Shared 7-Day Laboratory leaves 51 m^3 (1800 ft^3) for the standard sortie module subsystems and the sharing FPE equipment.

A summary of these envelope volumes for all the Life Sciecnes Laboratories is given in Table 4-1. In this table, the laboratory envelope volume is the total envelope around the Life Sciences equipment, excluding the baseline sortie module equipment. This envelope includes aisle-ways, access space, crew operation space, etc. Thus, it is much more than the actual research equipment volume contained within it. This equipment volume is listed in brackets in the table. The difference between the total sortie module internal volume and the laboratory envelope volume is that available for the baseline (standard) sortie module subsystems, and, in the case of the Shared 7-Day Laboratory, for the FPE sharing the sortie module with Life Sciences.

The layout of the Dedicated 7-Day Laboratory is shown in Figure 4-2. It occupies all of the volume above the floor of the sortie module except for the left end, as depicted where the standard DMS equipment is located. The laboratory contains 11 racks and consoles. Ten are for research equipment (see Table 2-2), and one is for subsystem equipment storage; namely, the recorders and tape for the DMS. Organism holding facilities include 6 cage modules and two small primate containers. The other major items are the laminar flow bench, which can interface with the holding units; the bicycle ergometer; rotating litter chair; teleoperator control console; and body mass measurement device. Many of these devices are exemplary in nature. That is, since it is not

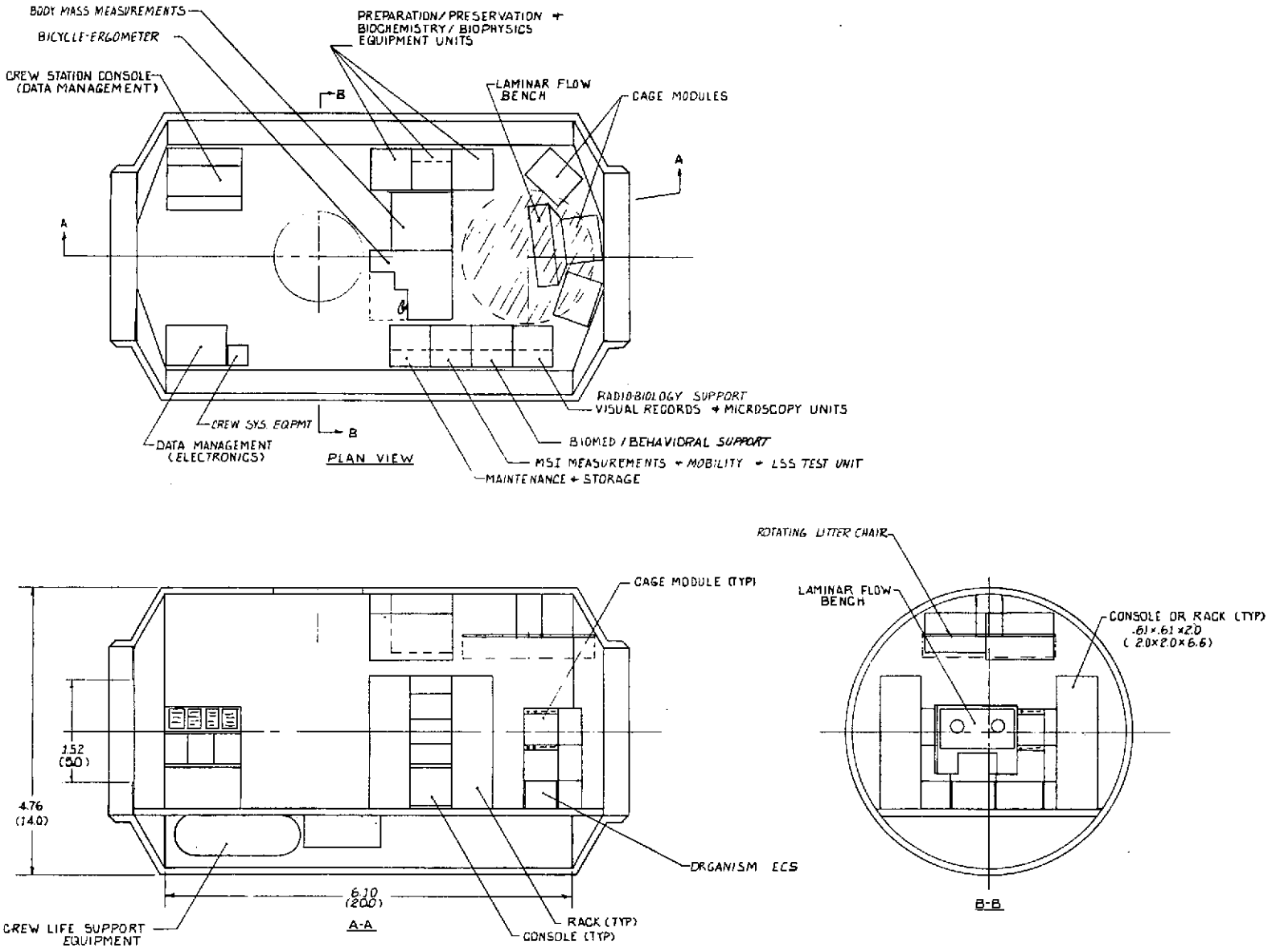


Figure 4-1. Equipment Layout in Shared 7-Day Laboratory

Table 4-1. Summary of Life Sciences Laboratory/Sortie Module Envelope Volumes

Volumes	Shared 7-Day Laboratory	Dedicated 7-Day Laboratory	Dedicated 30-Day Laboratory
Total Internal Volume of Sortie Module m^3 (ft^3)	87.8 (3100)	87.8 (3100)	87.8 (3100
Laboratory Envelope Volume, m^3 (ft^3) (Includes Research Equipment, Add-On Subsystems, Equipment, Aisles, Access Space, Etc.)	36.8 (1300)	59.5 (2100)	59.5 (2100)
[Research Plus Subsystem Equipment Volume within Laboratory Envelope Volume, m^3/(ft^3)]	12.5 (442)]	[17.6 (622)]	[20.6 (728)]
Remaining Internal Volume, m^3 (ft^3) (For Standard Sortie Module Subsystems Structure, Sharing Payload, Etc.)	51.0 (1800)	28.3 (1000)	28.3 (1000)

definitely known what devices will be used in future biomedical/MSI experiments, devices such as the rotating litter chair and bicycle ergometer have been included to be representative of the type of future equipment to be used. The Dedicated 30-Day Laboratory layout is shown in Figure 4-3 and is quite similar to the Dedicated 7-Day Laboratory. The addition of one rack and one console brings the total number of racks and consoles to 13 (including 12 for reserach equipment plus one for subsystem support), and requires a slightly more compact arrangement of items within the laboratory. The volumes of both the dedicated laboratories are summarized in Table 4-1.

An internal configuration for the sortie module, which is designated as having Z floors, is still being considered by NASA. As shown in Figure 4-4, it has two general floor levels rather than one, with a step in the upper level. In order to determine what impact the Z floors would have on the Life Sciences Laboratories, the Dedicated 30-Day Laboratory equipment was placed in this configuration. This laboratory contains the most equipment and was therefore used to indicate generally whether all the Life Sciences Laboratories would fit into the Z floors module. The Z floors laboratory shown in the figure contains both baseline sortie module subsystem equipment and Life Sciences research equipment. Since the floor-to-ceiling height is approximately 1.7m (5-1/2 ft), the standard racks and consoles that contain the Life Sciences equipment were reduced from 2m (6.6 ft) to 1.5m (5 ft). Thus, additional racks and consoles had to be added to make up for the lost volume. This resulted in 17 racks and consoles compared to 13 used previously. The remaining equipment is identical to that contained in the single floor version of the Dedicated 30-Day Laboratory.

All the single-floor laboratories require the placement of the MSI biomedical research specific equipment on the upper wall of the sortie module as depicted in Figures 4-1 to 4-3 (on the ceiling). This was necessary to get all the equipment into the sortie module, but does not adhere to the ideal case where all equipment is placed so that the crew assumes a common (heads-up) orientation. With the Z floors configuration, however, this equipment, which includes the bicycle ergometer, the rotating litter chair, the body mass measurement device, and teleoperator control console, can be oriented normally rather than upside down relative to the normal crew activity orientation.

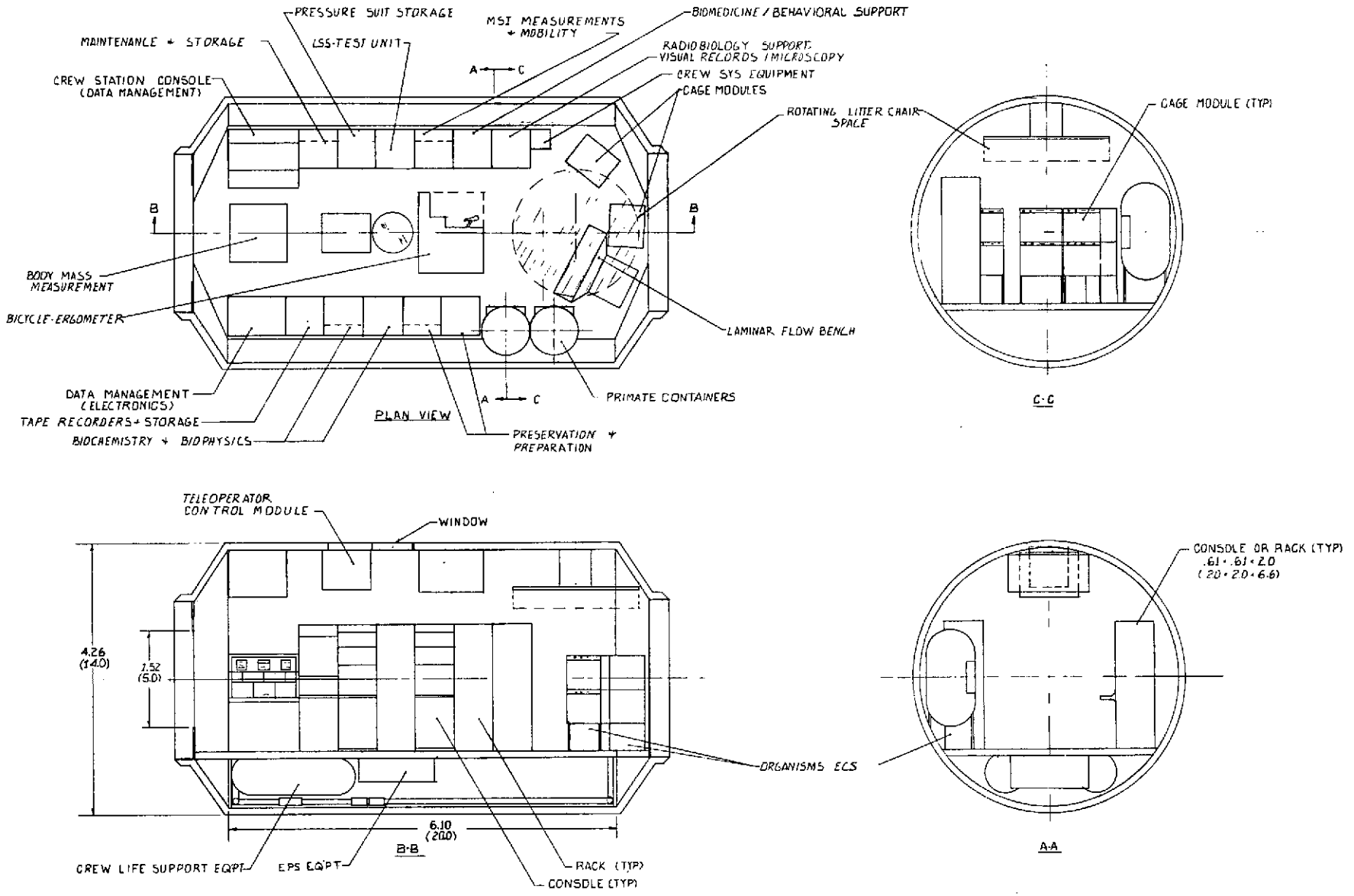


Figure 4-2. Life Sciences Equipment Layout in Dedicated 7-Day Laboratory

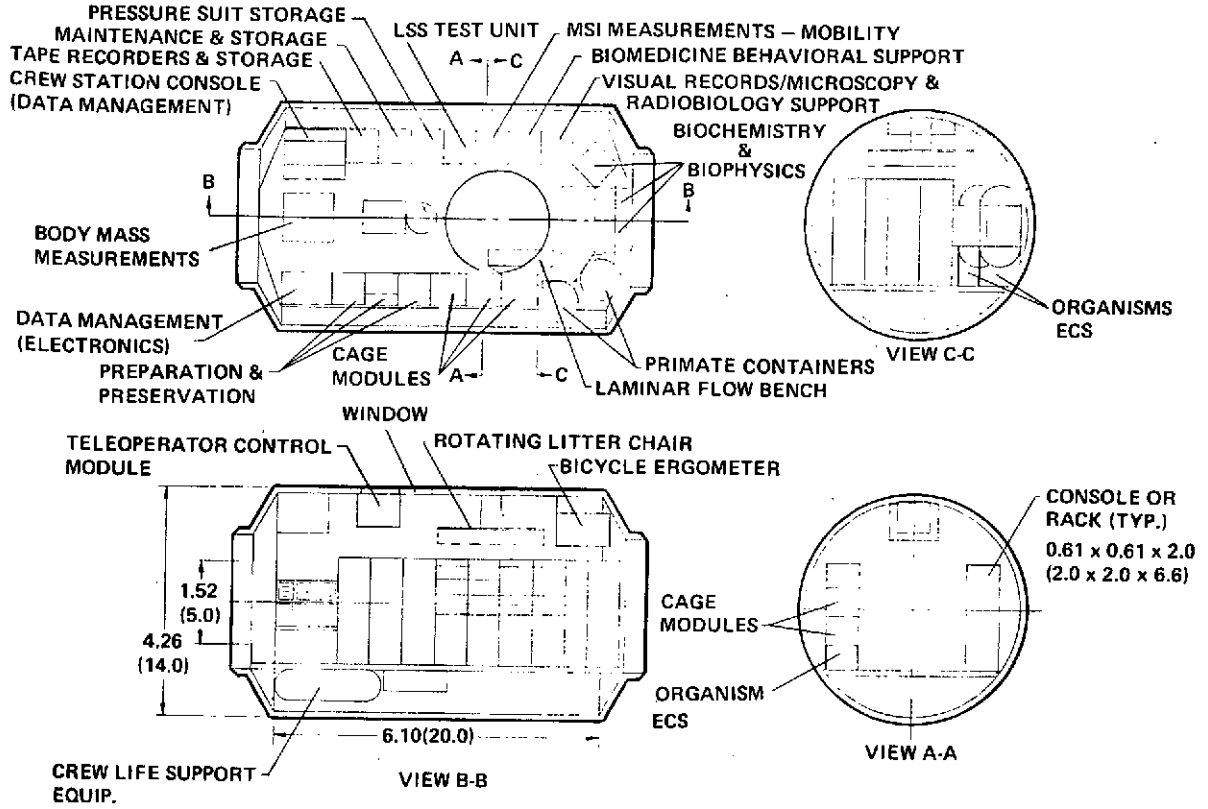


Figure 4-3. Equipment Layout in Dedicated 30-Day Laboratory

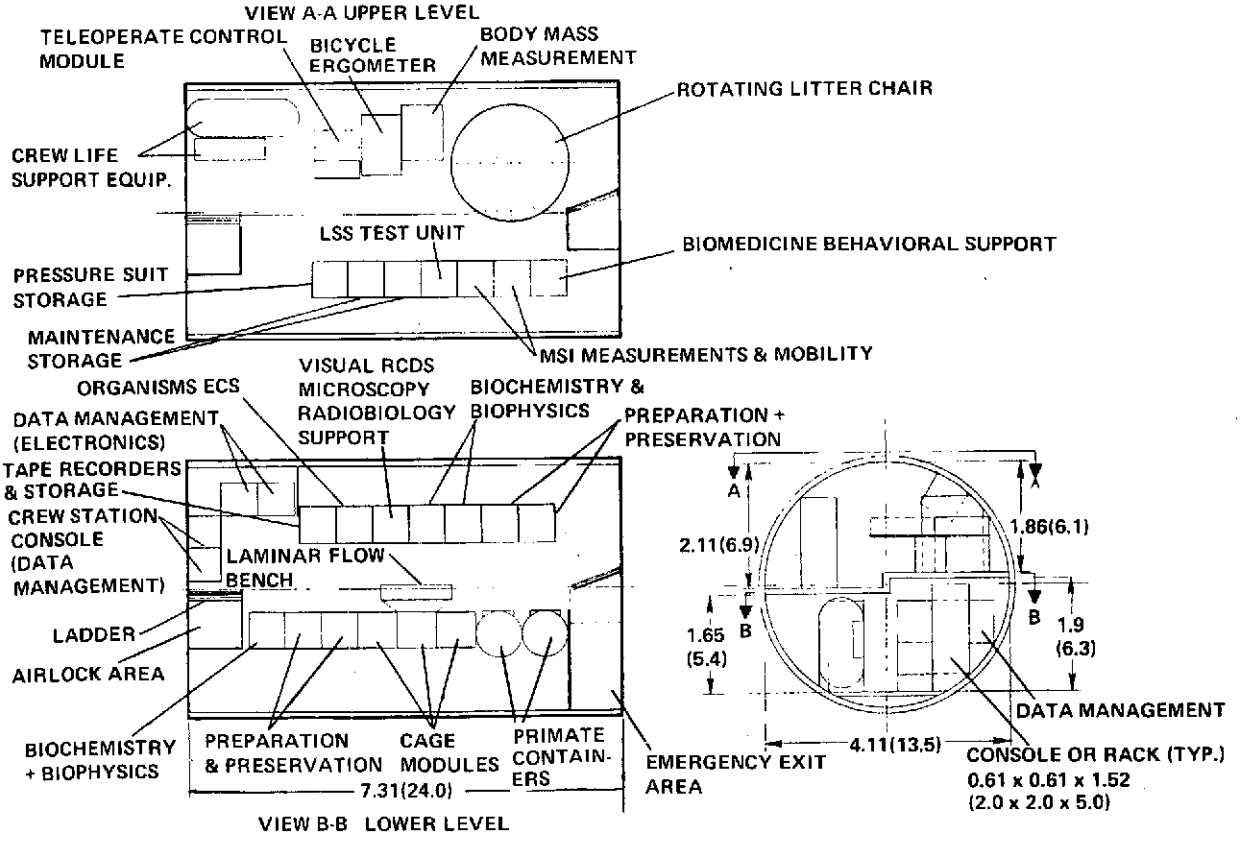


Figure 4-4. Dedicated 30-Day Laboratory Layout in Sortie Module with Z Floors

4.2 LIFE SCIENCES/SORTIE MODULE INTEGRATION SUMMARY

Table 4-2 summarizes the general requirements of the Life Sciences Laboratories and compares them with the shuttle/sortie module's capability to meet these requirements.

Table 4-2. Summary of Life Sciences Laboratory/Sortie Module Integration Parameters

Parameter	Available in Sortie Module	Life Sciences Payload Requirements		
		Shared Lab	Dedicated 7-Day Lab	Dedicated 30-Day Lab
Weight, kg				
Research Equipment + Supporting Rack and Consoles		2184	3300	4084
(Subsystems Equipment)				
Organism ECS		70	142	280
DMS Hardware & Research Recording Tape		171	397	1252
EPS Fuel & Tankage		130	155	1155
Thermal Control Subsystem		0	0	0
Crew EC/LSS		0	352	1047
Supporting Structure for Subsystem		37	105	373
Subsystem Subtotals		408	1151	4107
Total Weight, kg (lb)	5450 (12,000)	2592 (5702)	4451 (9792)	8191 (18,020)
Average Electrical Power, kW				
Research Equipment		1.13	1.59	1.90
Subsystem Equipment		0.20	0.59	0.67
Total	4 to 5	1.33	2.18	2.57
Electrical Energy, kW-hr	150	208	340	1850
Heat Rejection, kW_t	4 to 5	1.37	2.28	2.67
Sampled Data Acquisition Rate, kbps	100	<45	45	≈45
Sampled Data Downlink Rate, kbps	25-256	<50	50	≈50
Payload Specialists	2-4	1	3	3

The shuttle has payload capability of 14,500 kg (32,000 lb). Subtracting the 9,100 kg (20,000 lb) baseline sortie module design weight, leaves 5,450 kg (12,000 lb) for the Life Sciences Laboratories. As shown in the table, the Dedicated 30-Day Laboratory exceeds this weight capability. This problem area was found to exist late in the study due to a decrease in shuttle/sortie module weight capability guideline being used. Its resolution will require reduction of research capability or an increase in weight capability assignable to the experimental laboratory equipment.

Most of the other properties included in Table 4-2 have been previously discussed in Sections 2 and 3. The sortie module capability is generally sufficient to meet the Life Sciences requirements, or can be brought to a sufficiency level by adding equipment that has been charged to Life Sciences and included in the weight volume and power values for the laboratories. The details on the manning analysis that was performed leading to the mission specialist requirements are presented in Section 6.

SECTION 5

GROUND SUPPORT OPERATIONS AND FACILITIES FOR BIOLOGICAL FLIGHT RESEARCH

Typical activities in the pursuit of biological research in space were studied to determine any special ground facilities required and flight integration problem areas. Biological research was specifically studied because of certain differences between this area and the areas of biomedicine, MSI and life support and protective systems (LSPS). The main difference is that numerous types of experiments in the latter three areas have been conducted in previous manned space flights, whereas very few experiments have been performed with biological organisms. Aside from early flights using primates, attempts with unmanned satellites containing organisms and simple microbiological experiments the area of biological research in space, is relatively undeveloped.

Another difference between biology and the other FPEs is the requirement for comprehensive ground controls. In a complex biological organism, the interactions of many parameters can influence the parameter under study and an attempt must be made to isolate the experiment variable. Hence, the biologist uses control organisms to ensure that the introduction of some extraneous environmental condition is not responsible for the result he is observing. In contrast, the physical scientist (LSPS experiments) rarely uses such controls. Also, because of the variability of the various organisms, biological research is more of a statistical than an absolute phenomenon.

Similarly, biomedical research and MSI research are statistically oriented and require careful attention to experiment controls. The men to be used as subjects will undergo controlled testing before and after flight. However, the facilities for these tasks are in a large part presently available within the NASA centers.

In the area of biology, ground-based operations and facilities encompass a broad range of activities that are dependent on the specific experiments to be conducted. Typical activities were postulated here to determine potential facility requirements and integration problems. These activities are shown in the functional flow diagrams of Figures 5-1, 5-2, and 5-3. Table 5-1 also lists some of these activities and the associated facilities required. Any potential integration problems that can be foreseen at this time are also listed.

Figure 5-1 shows several activities anticipated during the mission preparation phase, between the time when specific experiments are selected until they are transferred from the principal investigators (PI) laboratory to the launch site. Following experiment selection, it may be desirable to verify that the experiment is compatible with the flight environment. At most, this activity may require that the proposed experiment be put through a ground simulation of the dynamic conditions to be experienced throughout the flight. This would include acceleration and vibration to determine whether

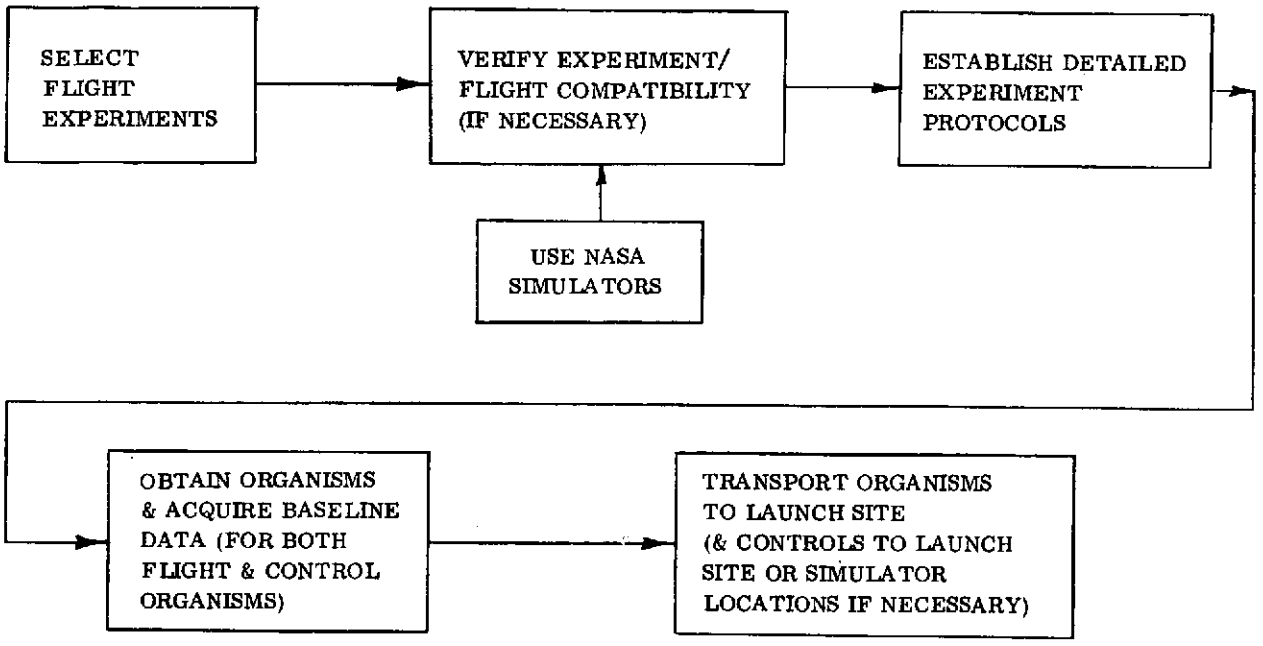
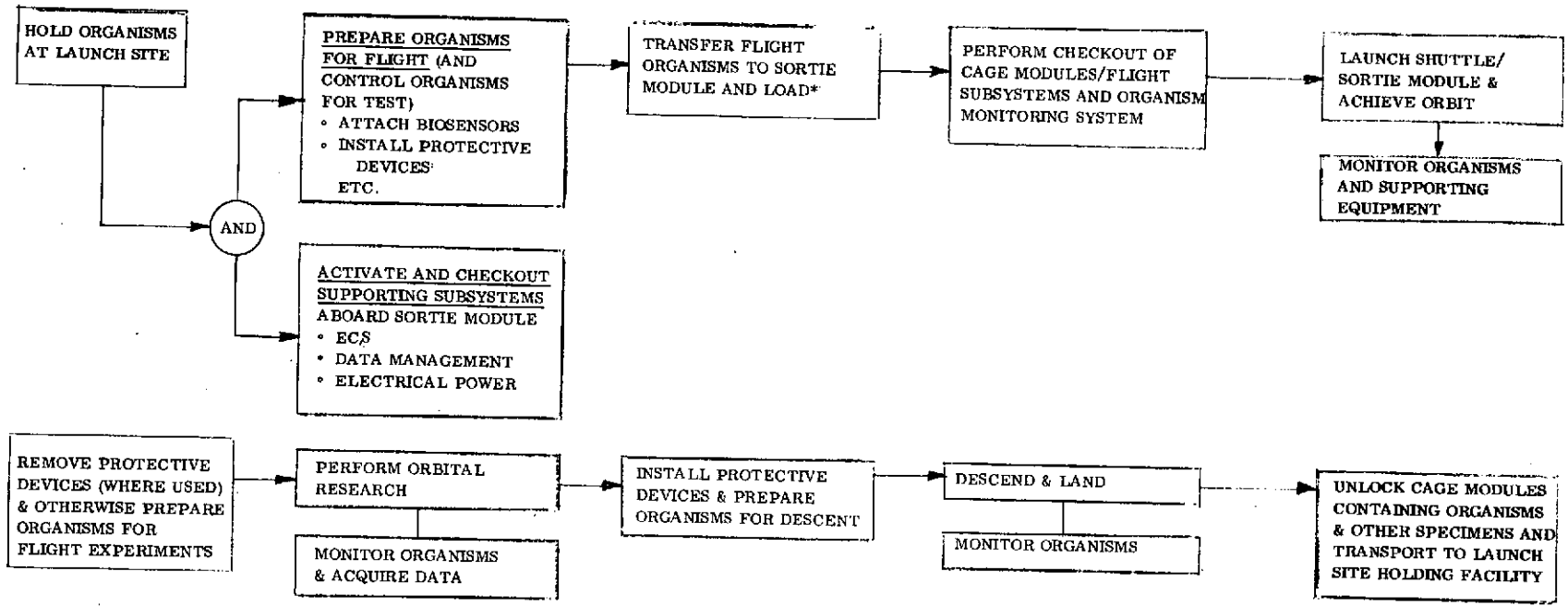


Figure 5-1. Potential Mission Preparation Activities

these forces substantially affect the organisms or the experimental measurements to be made. This would require a facility containing vibration platforms and probably a centrifuge to simulate ascent and descent acceleration. This equipment would have to be configured to accept living organisms and provide the necessary life support and monitoring for these organisms. NASA has equipment that could be adapted to this use at the various centers.

Other activities during the preparation phase, Figure 5-1, include the establishment of experiment protocols and baseline data and the transfer of the organisms to the launch site. During these activities, as well as throughout the program, the PI should be provided with organism-holding equipment similar to that which will be used in flight. For this purpose, Convair Aerospace has developed a cage module concept for housing various types of organisms. The cage module is a hermetically sealed enclosure that can be used in ground-based experiments as well as those in flight. It also provides a housing for the organisms as they are transported from the PI's laboratory to the launch site.

In addition to the cage modules for housing the organisms, certain supporting equipment will be required for environmental control of the cage modules, data acquisition, and electric power provisions. These functions will be provided during ground operations by a biological experiment support and transfer unit (BEST). The BEST is described in Section 10 and is designed to operate as a self-contained unit for the organisms within their cage modules. Therefore, this unit can be transported by ordinary ground or air transportation facilities.



*LOADING OF THE CAGE MODULES CONTAINING THE FLIGHT ORGANISMS WAS THE ASSUMED MODE OF LOADING. DURING THIS PROCEDURE, CAGE MODULES WITH SIMULATED ORGANISM LOADS WHICH WERE USED DURING COUNT-DOWN AND CHECKOUT PROCEDURES WOULD BE REMOVED AND REPLACED WITH THE CAGE MODULES CONTAINING THE FLIGHT ORGANISMS.

Figure 5-2. Major Ground Support and Flight Operations for Biology Experiments

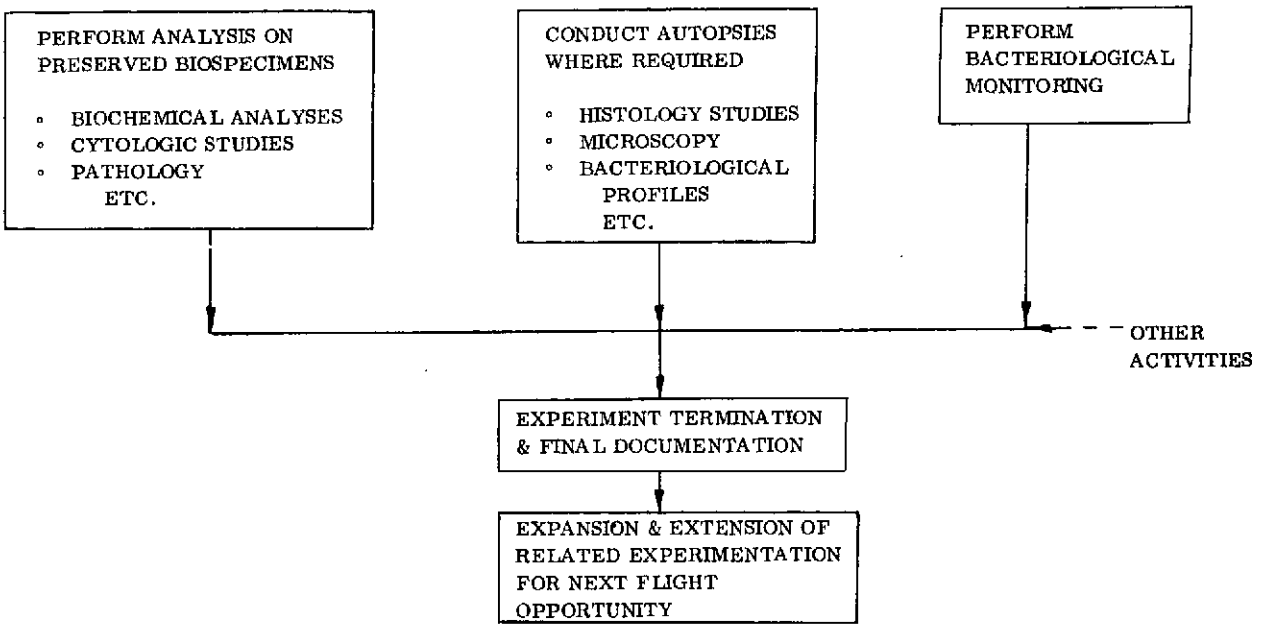


Figure 5-3. Example Postflight Activities

Figure 5-2 shows some of the major activities anticipated during the prelaunch and flight periods. The first block in this diagram indicates an anticipated requirement to hold the organisms at the launch site during initial countdown procedures. Organism holding at the launch site can also use the cage module holding units and the BEST to maintain a consistent and controlled environment for the organisms. The self-contained nature of the BEST will also minimize the facilities at the launch site, which will be necessary to support the organisms and experiments. However, depending upon the individual experiments, additional equipment may be required. Such equipment would be similar to that contained in the CORE equipment units of the equipment inventory, and would be used for monitoring the organisms during the preflight holding period. A suitable building with laboratory-type facilities would be required at the launch site to house the organisms and equipment.

Sometime during the preflight period, it is anticipated that certain preparatory procedures will be performed on the organisms and/or the cage module instrumentation and equipment. Examples include the attachment of biosensors and checkout of electronic equipment, and the installation of protective devices if required. Biosensors, however, may also be implanted at the PI laboratory rather than at the launch site, depending upon the specific experiment. Protective devices for protection of the organisms during their exposure to launch loads may be required for certain organisms such as plants.

Also, during the countdown period, the supporting subsystems aboard the sortie module will require checkout. During checkout, it was assumed that special-purpose cage modules with simulated organism loads would be used. This will allow loading of the

Table 5-1. Typical Biological Experiment Operational and Facilities Requirements

DESCRIPTION OF ACTIVITY	POTENTIAL ADDITIONAL GROUND FACILITY REQUIREMENTS	INTEGRATION PROBLEM AREAS
MISSION REQUIREMENTS		
A. Conduct Preliminary Tests to Determine Flight Compatibility and Research Protocols		
• At P.I. Laboratories	Use flight-type holding units (cage modules) with standardized supporting equipment (BEST).	Requires development and acceptance by the P.I. of standardized cage modules & BEST.
• At NASA Flight Simulation Facilities	Use cage modules and BEST. Use existing NASA centrifuge, vibration facilities and other dynamic loading equipment.	Potential problem in adapting NASA facilities for use with living organisms.
B. Prepare for Flight Experiment (Obtain flight and control organisms and acquire baseline data)	Use cage modules and BEST.	
C. Transfer Organisms and any Special Experiment Equipment to the Launch Site (Continue to monitor organism and experiment parameters)	Use cage modules and BEST for organism transport by standard ground or air transportation.	
LAUNCH SITE OPERATIONS		
A. Hold Organisms until Launch (Monitor	Biological laboratory facility.* Use cage modules and BEST.	
B. Install Organism Protective Devices just Prior to Launch (If required)	" " " "	
C. Activate ECS, DMS, EPS, & TCS and Check Out These Subsystems	Cage modules with simulated organism load for use during early checkout procedures.	Development of cage modules with simulated organism loads required.
D. Transfer the Flight Organisms in Their Cage Modules to the Sortie Module	Cage modules, BEST, standard ground transportation vehicle and mechanical loading devices.	Loading should occur as late in countdown as possible.
FLIGHT AND ORBITAL OPERATIONS		
A. Launch and Orbital Insertion	Use existing facilities.	Supporting subsystems must be functioning throughout the ascent phase of flight.
B. Remove Organism Protective Devices	None.	
C. Perform Experiments & Possibly Ground Procedures on Control Organisms	Use NASA ground-based biolaboratory at the launch site or P.I. laboratory.	
D. Reinstall Restraints & Protective Devices, & Descend to Landing Site.	None.	
IV. POSTFLIGHT OPERATIONS		
A. Transfer the Flight Organisms in Their Cage Modules to the Biological Holding Facility	Use cage modules, BEST, and standard ground transportation.	Transfer as soon after landing as possible.
B. Transfer Specimens to Biological Holding Facility	Need low temperature or insulated transfer containers.	
C. Perform Postflight Biological Analysis at the Biological Laboratory at the Launch Site if Required	Use launch site biolaboratory.	
D. Transfer Organisms and Specimens to the P.I.'s Laboratory	Use cage modules, BEST, and freezers. Use standard ground or air transportation.	
E. Perform Postflight Analyses at P.I. Laboratory and Terminate Experiment	Use existing P.I. facilities.	

*The Launch Site Biolaboratory would include facilities for such functions as organism holding, data management, microscopy studies, microbiological analyses, and anatomy and histology studies.

flight organisms in their cage modules later during the last few hours of the countdown (a requirement stipulated by bioscientists for certain short lifetime experiments). The cage modules used for earlier checkout will be identical to those to be used for flight and will be designed to allow checkout of the environmental control subsystem, electrical power subsystem, thermal control fluid loop, and data management subsystem. Just prior to loading the cage modules containing the flight organisms, the checkout cage modules will be removed. Following this, a final checkout of the flight cage modules is anticipated, as shown in Figure 5-2.

Following launch and orbital insertion, the organisms may require preparation for the orbital research procedures, including removal of protective devices, if used. Ground support activities during the orbital phase will depend upon the individual experiments being performed. If various research procedures must be performed on the ground controls, this could be done in PI laboratories using their equipment, or with controls held at the launch site biolaboratory, or at other NASA facilities. Control organisms would generally be held in the cage modules and supported by the BEST.

Following the orbital research period, organisms to be returned to earth will be prepared for descent, if required. As soon as possible after landing, the cage modules containing organisms will be removed from the sortie module and transported, using the BEST, to the launch site or PI biolaboratory. Specimens will also be transported to the biolaboratory, and may require special insulated or low-temperature containers for this purpose.

The postflight procedures may be performed at the launch site or at the PI laboratories. Typical examples of these procedures are shown in Figure 5-3.

An overall concept of the mission scenario for bioexperiments is shown in Figure 5-4.

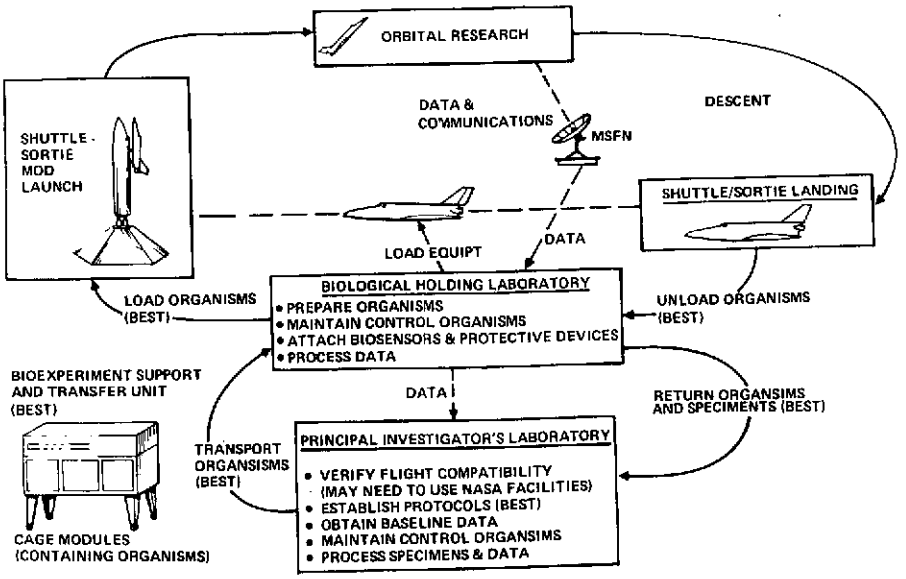


Figure 5-4. Bioexperiment Mission Scenario

SECTION 6

OPERATIONS MODEL DEVELOPMENT AND APPLICATION

A common technique used by designers of manned experimental facilities is to represent the operations within a facility by a set of typical experiments. This allows the designer to estimate operations-dependent quantities such as crew size requirements, power consumption levels, and equipment usage rates (of interest in workspace layout, data management calculations, etc.). This study, however, used a facility approach in the design of the Life Sciences Laboratory. Therefore, specific experiments could not be used as the basis for a laboratory design, which made it necessary to model the research operations in some other way. This section discusses the development of an operations model based upon a facility approach.

6.1 OPERATIONS MODEL

An operations model was developed based upon the Life Science research functions to be performed within the laboratories. These functions were taken from the computerized functions inventory developed during Task A and B, of the preceding contract. The equipment methods used, and the time required to perform these functions, form the heart of the operations model. A frequency of occurrence was estimated for each of the function-methods. This frequency, in conjunction with the function inventory performance time data, gives the designer a feel for the activities within the laboratory, how often they occur, and for how long. Thus he has a basis for estimating the operations-dependent quantities, such as workspace layout, power levels, data management requirements, etc.

The complete operations model is tabulated in Volume III, Appendix II. The first page of this 23-page model is shown in Table 6-1. The functions and their selected equipment methods are listed in the left-hand column. The estimated time to complete the function is listed in the next two columns; the first column is the time estimate if the function-method is performed just once; the second column is the time estimate for each additional repetition (it generally is smaller as the unstow, setup, restow type of activities are included in the first time estimate).

The next three columns are the estimated frequency of occurrence of the function-method for the Dedicated and Shared laboratories and an explanatory note column. The estimated frequencies are stated as the number of repetitions of a given function or method per time period (or where a time estimate was not provided in the inventory, an activity time estimate per time period).

It should be recognized that functions frequently do not occur at regular intervals but are of a more sporadic nature. For example, a function might occur ten times one

Table 6-1. Excerpt From Operations Model

OPERATIONS MODEL

FUNCTION	TIME REQUIRED PER REPETITION, MIN.		FREQUENCY *			CREW TIME REQUIRED (Min./Time Period)	
	First Repetition	Succeeding Repetitions	Dedicated Lab (7 & 30 Day)**	Shared Lab (7 Day)	Notes	Dedicated Lab (7 & 30 Day)	Shared Lab (7 Day)
3 Vertebrate feeding - solid pellets are supplied adlib or regulated							
A Pellets attached to belt	0	0	C[1]	C		A[2]	A
4 Vertebrate watering - req dripless animal actuated dispensor tips							
A Manifold low pressure to tips	0	0	C	C		A	A
5 Urine mgmt at cage - urine must be removed quickly (minutes) Air flow thru cage moves urine to collection pad.							
A Lam air flow system as appo	0	0	C	C		A	A
6 Urine mgmt from cage collector to storage or disposal							
A Urine pad exchanged	20	2	1/wk	1/wk		20/wk	20/wk
8 Feces mgmt - cage to disposal liquid to solid consistency							
B Feces collected through LFB	20	1	1/wk	1/wk		20/wk	20/wk
9 Organism mass measurements							
A Oscillating mass measurements	5	5	1/3 dys	1/wk		5/3 dys	5/wk
10 Holding primates MMB - measures basic metabolism at work/rest							
C Modified primate holding cylinder	60[1]		1/2C	-		A	-
11 Holding rat and rat size animals for metabolic msmts							
A Special cage with many xdcrs	20		1/2C	-		A	-
12 Holding mouse MMB - same as for rat							
A Special cage with many xdcrs	20		1/2C	-		A	-
13 Holding cage MMB - rabbits/marmots, etc.							
A Special cage with many xdcrs	20		1/2C	-		A	-
14 Bioelectic xdcr installation and setup - beware emi							
B Crt check/precalib comptr cal	15	5	2/2 dys	-		20/2 dys	-
C Preinstal	1	1	1/dy	1/dy	Crew checkout	1/dy	1/dy
15 Camera setup							
A Mount, function ck and calib	20	10	1/dy	-		30/dys	-
16 Setup camera optical commutation-organism to organism							
C X-Y camera drive	1/5C	-	1/5 C	-		A	-
17 Monitor ECG (for bioresearch - ecg signal mgmt from cage to cage mod to data mgmt.)							
B Hardware multiplex data to dm	5	0	C	-	3/wk crew checkout	9/wk	-

* Or minutes/time period where appropriate.
** Data in parenthesis are for 30-day lab only.
1 "C" indicates a continuous function.

2 "A" indicates an automatic function with no crew time required except for initial equipment setup. This time is estimated in the "First Repetition" column but not used in the manning analysis.

day and only twice the next, or every hour for two days and then not at all for the rest of the week. Average frequencies have been assumed for these functions.

The estimated frequencies were constrained by practical considerations for some functions. As an example, the frequency with which a sample of blood can be drawn from a rat is bounded by the need of the experimenter on the one hand, and exsanguination of the rat on the other. For other functions, an intuitive estimate of the expected frequency of a particular function within the laboratory was used. The expectted frequencies are considered to be reasonable estimates representative of the character of the operations within the laboratory. The final columns in Table 6-1 are crew time estimates in the manning analysis discussed below.

6.2 MANNING ANALYSIS

The operations model was used as the basis for estimating total crew time requirements (work load). To determine the crew size required, the work load was divided by the time available per crewman. Available crew time was constrained by the assumed duty cycle for each laboratory.

6.2.1 DUTY CYCLE. The basic duty cycle assumed was 12 hours on duty and 12 hours off duty, seven days a week, with the entire crew on duty at the same time and sleeping at the same time. Five days out of the 7-day missions were assumed to be devoted to experimental activities, and 6 out of every 7 days on the 30-day missions, as discussed below.

6.2.1.1 Simultaneous Duty Cycles. The selection of a simultaneous duty cycle was based on the Life Sciences Laboratory requirements. No experiment requirements for round-the-clock (RTC) operations have been identified for these laboratories. The all-on, all-off operation was selected in order to:

a. Increase the availability of crew skills. When the crew is split in half with RTC operations, one of two procedures must be followed. All activities requiring a certain skill must be scheduled during one-half of the day. If this were done, certain operations would require crewmen to be awakened during their sleep period to serve as subjects on tests conducted by this specialist. It would also limit Life Sciences research by reducing the number of crew skills available at any particular time, this reducing the overall versatility of the laboratory in applying all the skills available as the immediate situation demanded. The alternative to splitting skills is cross-training crew members to an even greater degree than otherwise required. Cross-training of crewmen to acquire the variety of skills demanded by the Life Sciences Laboratory will be required even when all the crewmen are available at one time. This requirement would be further compounded by RTC operations.

b. Minimize noise during sleep periods. Recommendations from ground-based simulations of long-duration spaceflight and past space experience consistently contain references to continuing efforts to minimize noise during sleep periods. Noise can be a major irritant to the crew, and even with separated living quarters, the active crew would disturb the sleeping crew when they return to the crew quarters for meals, etc.

c. Maintain ground biorhythms. To maintain peak performance during the initial adjustment phases of the mission, the all-on, all-off schedule allows continuation of the crew's ground-based wake/sleep cycle, and no readaptation of their biohythms is required.

6.2.1.2 Off-duty Time. The 12 hours of off-duty time for each crewman are divided into: 1) 8 hours of sleep; 2) 2.5 hours of food preparation, meals and cleanup, or about 45 minutes for each of two meal periods, and an hour for the third; and 3) 90 minutes of exercise and personal hygiene activities. Periodic housekeeping of the living quarters is assumed to be completed during this latter time period as required.

6.2.1.3 On-duty Time — 7-day missions. For the 7-day missions, the 12 hours of on-duty time are completely scheduled with functions from the function inventory. Any unscheduled activities, such as emergency repair or replacement of equipment or high-priority unscheduled experimental activity selected by the on-board experimenter, would replace scheduled experiment activity, causing it to be rescheduled and performed later if time was available. Five of the seven days are scheduled for experiment activity, with the first and the seventh day devoted to launch, orbit establishment, checkout, and setup activities and shutdown and re-entry activities.

6.2.1.4 On-duty Time — 30-day mission. For the 30-day mission, the scheduled activity is reduced to ten hours, with a 2-hour allotment for contingency time to account for the greater probability of equipment breakdown on a longer mission, to provide for a larger margin of error in scheduling activities over the longer mission, and to provide the potential for crew personal or recreational time should circumstances warrant it and the need arise.

Six out of every seven days are devoted to experiment activities after initial orbit and setup have been achieved. A highly flexible seventh day is provided, with no scheduled activity from the functions inventory. This day is scheduled as an experiment evaluation and review time between the on-board experimenter and ground-based principal investigators to take full advantage of the research flexibility allowed by manned laboratories in space. The scheduled activity for the coming week would be thoroughly evaluated based on the experience of the past week, and potential changes or repetition of measurements planned. In addition, this day would provide contingency time for abnormally high maintenance and repair activity, and for crew personal and recreational time as required by the long-duration mission.

Table 6-2. Crew Size Required for the Life Sciences Laboratories

	TOTALS		
	DEDICATED LAB		SHARED LAB
4205 min/wk =	4205 min/wk	1473 min/wk =	1473 min/wk
753 min/dy =	3765 "	345 min/dy =	1725 "
520 min/3 dy =	1040 "	55 min/3 dy =	110 "
60 min/2 dy =	180 "	14 min/2 dy =	42 "
11 min/4 hrs =	165 "	0 min/4 hrs =	0 "
	9355 min/wk		3350 min/wk
2-man functions =	2279 min/wk	2-man functions =	892 min/wk
or @ 50%* =	1139 min/wk	or @ 50%* =	446 min/wk
	10494 min/wk		3796 min/wk
Crew size required =	10,494/3600**	=	3796/3600**
=	2.93 men (a 3-man crew)	=	1.06 man (a 1 man Life Sciences crew)

*Assuming the second man can work 50% of the time on another task.

**Assuming crew time available for experimental activities equals 12 hours a day, five days a week (10 hrs a day, six days a week for Dedicated-30), or 3600 min/wk.

6.2.2 MANNING LEVEL. The number of men required to perform the desired tasks in the Life Sciences Laboratories was determined by calculating the total crew time required and dividing that by the time available per crewman. Crew time required, or workload, is tabulated in the two right-hand columns of the Operational Model, Appendix II, Volume III for each function-method requiring crew involvement. It is also illustrated in the excerpt from the Operations Model, Table 6-1. It was calculated by multiplying the time required for each function-method times its estimated frequency. The sum of these products is shown in Table 6-2 for the Dedicated and Shared Laboratories. For those biomedical and man-system integration functions that require two men (a subject and experimenter), it was assumed that the experimenter could spend approximately 50 percent of his time on other activities while the two-man function was being completed by the subject (some functions require an experimenter only during initiation and termination, while others require him full time). Thus, only 50 percent of the total two-man function time was added to the subtotal to obtain the total workload estimate for each laboratory. The Shared Laboratory requires one man devoted to Life Sciences activities, while the Dedicated 7-Day Laboratory requires approximately three men.

The Dedicated 30-Day Laboratory has some increased functional capability over the Dedicated 7-Day Laboratory, but the additional crew time requirements are approximately offset by the decreasing frequency of occurrence of some of the functions (e.g., those functions whose frequency is limited by the supply of animals such as the function "gross anatomies"). Therefore, while a detailed analysis was not performed, it is felt that the Dedicated 30 manning requirements are approximately the same as the Dedicated 7.

The above manning requirements are compatible with current estimates of crew size for the sortie module.

6.3 EQUIPMENT OPERATIONS ANALYSIS

The operations model was used as the basis for estimating average power consumption and equipment usage rates. This procedure, equipment operations analysis, is documented in the Volume III, Appendix I. It indicates what each equipment item within the EU is used for, how often it is used, and the average power it consumes.

An excerpt from the Equipment Operations Analysis Table for EU 4 (Preparation and Preservation Unit) is shown in Table 6-3. Each equipment item is listed by identification number (left-hand column), and name (second column). The remaining columns indicate, for each laboratory, the number of that item required, the estimated frequency of occurrence of each using function, the crew use time for each equipment item (per function and total use time), and an average power consumption (per function and total).

The crew use time was obtained by multiplying the function frequency times the crew time required to complete each function, which is listed in the function inventory. This product was converted to crew use time in minutes per day, so that each crew time per function could be added to obtain a total crew use time for each equipment item. This total can be used during the laboratory layout task for gross estimations of the work space volumes required around an equipment item. For example, is more than one crewman accessibility desirable? Is crew occupancy of the access work space so high that special provisions are necessary for passage by other crewmen? Are special provisions for access to adjacent items necessary to minimize interference? The individual equipment use times can also be used if payload trimming of borderline items is necessary to cut cost, weight, power, or volume. For example, if a heavy item was used infrequently, it would be a candidate for a tradeoff between its in-space usefulness and the weight savings obtained if this function could be performed on the ground.

Table 6-3. Sample From Equipment Unit Data Package — Equipment Operations Model EU 4 — Preparation and Preservation Unit

EQUIP. ITEM	EQUIPMENT NAME & USING FUNCTION	DEDICATED LABS – 7 & 30 DAYS				SHARED 7-DAY LAB			
		NO. OF ITEMS REQD.	FUNCT. FREQ.	CREW TIME, MIN/DAY	AVG. POWER, WATTS	NO. OF ITEMS REQ'D	FUNCT. FREQ	CREW TIME, MIN/DAY	AVG. POWER, WATTS
014	ANESTHETIZER (INVERT HANDLING)	1				1			
	78A INVERTEBRATE COUNTING & SORTING		15 MIN/DY.	15.0 15	0 0		5 MIN/DY.	5.0 5	0 0
018	BENCH, LAM FLO	1				1			
	6A URINE MANAGEMENT		1/WK.	4.0	0.6		1/WK.	4.0	0.6
	8B FECES MANAGEMENT		1/WK.	4.0	0.6		1/WK.	4.0	0.6
	31B BIOSAMPLING		6/DAY	30.0	4.2		3/DY.	15.0	2.1
	78A INVERTEBRATE COUNTING & SORTING		15 MIN/DY.	15.0	2.1		5 MIN/DY.	5.0	0.7
	91B PLANT RADIOCHEMISTRIES		–	–	–		2/WK.	8.0	1.1
	92B VERTEBRATE RADIOCHEMISTRIES		4/WK.	16.0	2.2		2/WK.	8.0	1.1
	93B INVERTEBRATE RADIOCHEMISTRIES		4/WK.	16.0	2.2		2/WK.	8.0	1.1
	94B CELL & TISSUE RADIOCHEMISTRIES		4/WK.	16.0	2.2		2/WK.	8.0	1.1
	124A CREW/ORGANISM ISOLATION		1/4 HR.	9.0	1.3		1/DY.	3.0	0.4
	125A CREW/CHEMICAL ISOLATION		1/4 HR.	9.0	1.3		1/DY.	3.0	0.4
	353A CULTURE/SENSITIVITY		1/WK.	1.0 120	0.1 17		–	– 66	– 9

A similar technique was used to obtain average power consumption. The power consumption rate required by each equipment item was multiplied by the average fraction of time per day that each EI would be used per function to obtain the daily average power consumption rate for each EI per function. These values were than added to obtain the total daily average power consumption rate for each EI, for each EU, and finally for each laboratory. The average power in the equipment operations analysis tables has been rounded off to the nearest watt. In many cases, a zero appears in the column where power is being consumed, but only for a short time, so that on daily power basis it is nil.

This operations analysis of each equipment item allows us to identify quantities such as average EU power consumption rates and the highest individual power consumers, as discussed below.

6.3.1 AVERAGE POWER BY EQUIPMENT UNIT. The average power consumption rate for each EU is shown in Table 6-4. Two totals are shown for each EU in each laboratory. The first total represents the average power consumption rate while the crew is doing research within the lab (on-duty power). The second number represents the power consumption rate for the off-duty hours and is obtained by summing the average power consumption rates for that equipment which continues to function automatically, with or without the crew.

6.3.2 AVERAGE POWER BY LARGEST CONSUMERS. Those equipment items which draw the largest amount of power, on a daily basis, are listed in Table 6-5. These 22 out of a total of 198 equipment items Dedicated (30-Day) Laboratory use 88% of the power. The items are ranked by average power required for all units of one type. For example, the 16 rat cages draw an average power of 72 watts every 24 hours.

Table 6-4. Average Power Consumption by EU, Watts

	Shared		DED-7		DED-30	
EU	On-Duty	Off-Duty	On-Duty	Off-Duty	On-Duty	Off-Duty
1	224	219	261	237	271	246
2	103	100	155	146	155	146
3	20	20	65	64	65	64
4	257	85	277	85	541	335
5	88	80	315	225	320	225
6/7	10	0	27	0	27	0
11	0	0	0	0	0	0
12/31	26	6	56	6	56	6
26	5	0	14	0	15	0
40/41/42	82	82	195	195	230	230
50/51/70	130	130	131	130	131	130
60/61	100	100	100	100	100	100
80	200	200	200	200	200	200
91/93	0	0	2	0	4	0
Totals	1245	1022	1798	1388	2115	1682

Table 6-5. Largest Power Consumers (DED-30)

EU	EI	Name	Average Power Consumption (Watts)
4	81	Freezer, Low Temperature	250
1	32A	Camera Controller	200
80	115F	LSS Test Bench	200
4	179	Temperature Blocks	150
5	89	Gas Analyzer, GC (Complex)	139
41	28A	Cage, Monk, Macac	100
60	98A	Holding Unit Incubator, Cells	100
5	91	Gas Analyzer, Mass Spec	80
40	30A	Cage, Rat/Hamp/Quail	72
4	80	Freezer, General	70
50	101	Holding Unit, Plant	70
2	156	Signal Conditioners	63
5	7	Autoanalyzer, Multiple	61
2	63B	Display-Keyboard Console	60
70	98C	Holding Unit Incubator-Inverts	50
3	1A	Accelerometer Couplers	41
12	153A	Rotating Litter Chair	39
1	37	Camera, Video B/W	35
41	100	Holding Unit, MMB, Primate	35
3	150D	Receivers, DC-5 mhz	20
5	50A	Commutator, Gas Manifold	20
42	150B	Receiver-EXG, Cage Mod	20
			1875
			or 88% of total average power

SECTION 7

CARRY-ON LABORATORY DEFINITION

The current study included not only the definition and integration of the large Life Sciences sortie module laboratories, such as the Shared and Dedicated laboratories, but also the definition of smaller, portable, primarily self-contained laboratories that could be placed in the multipurpose sortie lab or the crew compartment of the shuttle orbiter to provide the capability for limited experiments on the early shuttle flights. These carry-on laboratories were included in the current phase of the study by NASA direction and did not receive the Task A and B analyses. Consequently, they have not been defined at the same level as the larger laboratories. The material presented in this section is on the conceptual design level only.

7.1 REQUIREMENTS AND GUIDELINES

The definition of the carry-on laboratories was guided by NASA directives, including a listing of the research areas of primary interest, the functional capabilities desired in each area, a set of requirements, and a set of tentative constraints (Reference 9).

The functional capabilities desired in each research area were reviewed, and the equipment needed to provide that capability was identified. This selection process was guided by (1) the NASA requirement to minimize the data analysis performed in space, emphasizing sample return for ground analysis, (2) the requirement for modular design to ease removal and replacement of components, and (3) the requirement for maximum equipment commonality within and between FPEs. Wherever possible, CORE equipment items were selected from CORE inventories to form the heart of the laboratories. The CORE items were supplemented by certain discipline-specific equipment, such as the cage module used to confine sub-human test specimens. However, these, too, were chosen because of their broad applicability across the disciplines, their multiple-purpose capability, and their reusability (basically CORE-like characteristics).

Other requirements that were specified were the need for isolated test environments to prevent cross-contamination in biology and biomedicine and the use of off-the-shelf equipment wherever possible.

The set of tentative carry-on laboratory constraints provided by NASA are listed in Table 7-1. These constraints, imposed by the potential placement of the laboratories in the orbiter-crew compartment, are subject to revision and were to provide initial guidance only and not inviolable limitations.

This task resulted in the conceptual design of five laboratories: two in biology and one each in biomedicine, man-systems integration (MSI), and life support and protective systems (LS/PS).

Table 7-1. Carry-On Laboratory Constraints

Weight	136 kg (300 lb)
Power Requirements	
Sustained	100 Watts
Peak	500 Watts
Volume	0.85 m^3 (30 ft^3)
Maximum Package Dimensions	0.61 m × 0.76 m × 0.91 m (3 ft × 2.5 ft × 3 ft)
Packing Density	
Maximum	320 kg/m^3 (20 lb/ft^3)
Average	160 kg/m^3 (10 lb/ft^3)
Crew Time	1 hr/day

7.2 BIOLOGICAL AND BIOMEDICAL CARRY-ON LABORATORIES

Our approach to the conceptual design of the Biological and Biomedical Carry-on Laboratories was similar, so the design of both laboratories will be discussed together.

7.2.1 RESEARCH AREAS OF INTEREST FOR THE BIOLOGICAL CARRY-ON LABORATORY. Many problems of interest in the support of man in advanced space systems cannot be approached by using man as the test subject in short sortie flights, because the flight duration is too short to permit observation of significant changes in man's physiology. Moreover, many studies involve techniques that may be adverse to man except under a specifically controlled medical environment. It is therefore appropriate to use biological models in place of man for such research.

Two Biological Carry-on Laboratories were specified to illustrate the use of biological models in sortie flights. One employs whole living organisms (small mammals) as the model. Various mammals of choice could be used for evaluating different physiological systems. The other laboratory is based on the use of selected cells and tissues to observe intimate details of responses to zero-g over comparatively short time scales.

7.2.1.1 Small Mammal Carry-on Laboratory. The facilities for confining specimens are based around the rat as a test subject; however, any small mammal of comparable size can be accommodated. Cardiac function and hemodynamics were specified as the research areas of interest to parallel similar work done on man. As in the Medical payload, certain measurements would be made in real time, while a wide variety of body fluid samples would be preserved for later study. The animals could be returned alive to earth, or the whole specimen, any organ, or tissue could be preserved for postflight analysis in ground laboratories. The emphasis on preservation and return for ground study has a significant impact on laboratory characteristics.

7.2.1.2 Cell and Tissue Carry-on Laboratory. A general facility for maintaining and experimentally manipulating cell and tissue cultures is provided. Studies of electrolyte balance and mineral metabolism can be accomplished with this laboratory. A preparation and preservation capability is particularly important in the cell and tissue area. Cultures may be returned both alive and fixed for ground study.

Bacteriological survey studies of man and his shuttle environment are feasible with this laboratory.

7.2.2 RESEARCH AREAS OF INTEREST FOR THE MEDICAL CARRY-ON LABORATORY. This laboratory focuses on some of the early changes in man's physiology as he adapts to the space environment. The research areas of interest included are:

a. Cardiac function.

b. Hermodynamics (including studies of cells, electrolytes, and other blood components).

c. Pulmonary function.

d. Fluid compartment studies.

e. GI function .

f. Excretory function.

g. Metabolism.

In-flight measurement of cardiac and certain hemodynamic and pulmonary functions is provided. The means to obtain and preserve all necessary body fluids, solids, and fractions thereof for ground analysis are included. The latter mode of data gathering will be particularly pertinent to the study of blood chemistries and GI, excretory, and metabolic functions.

7.2.3 CONCEPTUAL DESIGN. The conceptual design analysis for the biological and biomedical laboratories consisted of examining each of the desired functional capabilities (research tasks) and the type of data sample that would result from that task. Tables 7-2 through 7-5 are the worksheets used for this analysis. From these data, it was determined whether comparatively complex instrumentation would have to be placed on board the laboratory to record the experimental data (e.g., electrophysiology data samples), or whether minimal equipment could be placed on board to collect and preserve the sample, with later analysis performed on the ground (e.g., urine samples). The size of the data sample was estimated, where appropriate, and the need for special preservatives was identified, as was the type of storage required. Finally, the crew time required for each task was estimated. This process identified the required equipment for each laboratory. The equipment list for the Biomedical Small Vertebrate and Cells & Tissues Carry-On Laboratory are presented in Tables 7-6 through 7-8.

Similar modular designs are proposed for the biological and biomedical laboratories. The configuration would be modified to meet the requirements of a specific FPE by the installation of appropriate kits. This modular design is illustrated in Figure 7-1, including the dimensional envelope and functional relationship between the two modules, the holding unit module (HUM) and the bioresearch support module (BRS).

Table 7-2. Function List and Technical Requirements, Biomedical Research Carry-On Payload — Physiodynamics

INVENTORY NUMBER		FUNCTION DATA: SPACE ANALYSIS	ANALYSIS: GROUND ANALYSIS	ANALYSIS: ELECTROPHYSIOL.	SAMPLE: AIR, EXPIRED	SAMPLE: AIR, PARTICULATES	SAMPLE: AIR, BACTERIA	SAMPLE: GASTRIC (VOMITUS)	SALIVA	URINE	FECES	PRESERVATIVE	VOLUME (ml or Gms)	REFRIGERATION	FREEZING	LYOPHILIZE	STORAGE TIME (days)
	CARDIAC FUNCTION																Preserv./ Prepare
218	Cardiac Output	X		X													4
161A	Arterial Blood Pressure	X		X													3
319A	Vectorcardiogram	X		X													5
320A	Phonn/Vibrocardiogram	X		X													5
321A	Impedance Cardiography	X		X													5
324A	Pulse Wave Velocity	X		X													4
325A	Pulse Wave Contour	X		X													4
424A	Carotid Body Stim. Response Meas.	X		X													5
	PULMONARY FUNCTION																
330A	Respiratory VD, VA, VR	X		X	X												1
331A	Respiratory Airway Resistance	X		X	X												4
332A	Lung Compliance	X		X	X												5
	GASTROINTESTINAL FUNCTION																
369A	Stool Preservation		X								X	100		X			8
412A	Fecal Mass/ Wet Weight Measurement		X								X	1-200		X			5
411A	Mineral Balance		X								X	100		X	X		5
	EXCRETORY FUNCTION																
406A	Urine, Microscopic Analysis		X							X		50		X			10 min. Or all pres/pre 406A through 487A
407A	Urine, Chemical Analysis		X							X		20		X			
411A	Mineral Balance		X							X		50		X	X		
418A	Urine Volume	X								X		prn					
431A	Urine, Calcium		X							X		5		X			
431A	Urine, Mucoproteins		X							X		5		X	X		
435A	Urine, Pyrophosphates		X							X		10		X			
436A	Urine, Hydroxyproline		X							X		10		X			
457A	Urine, Total Amino Acids		X							X		50		X	X		
458A	Urine, Aldosterone		X							X		50	X				
459A	Urine, ADH		X							X		50	X				
460A	Urine, 17-Hydroxycorticosteroids		X							X		100	X				
461A	Urine, Ketosteroids		X							X		100	X				
462A	Urine, VMA		X							X	HCl	100	X				
463A	Urine, Metanephrines		X							X		100	X				
464A	Urine, Catecholamines		X							X		100	X				
465A	Urine, Histamines		X							X		100		X			
466A	Urine, Serotonin (5-HIAA)		X							X		100	X				
467A	Urine, Sulfate		X							X		50		X			
	METABOLIC STUDIES																
411A	Mineral Balance		X					X	X	X	X	gs ceq.		X			8
418A	Urine Volume	X								X		prn					5
419A	Nitrogen Balance		X								X	100		X			8
420B	Caloric Intake	X															
421A	Water Consumption for Man	X															
300A	Vomitus Collection		X					X						X			5
301A	Vomitus Prsv. and Storage		X					X						X			5
302A	Sweat Sample Collection		X						X					X			5
303A	Sweat Prsv. and Storage		X						X					X			5
141A	Air Sampling	X		X	X								X				10
142A	Microbiological Sampling		X		X		X	X	X	X	X		X				15

Table 7-3. Function List and Technical Requirements, Biomedical Research Carry-On Payload — Hemodynamics

FUNCTION DATA		ANALYSIS		SAMPLE				COLLECTION		EQUIPMENT UNITS						
INVENTORY NUMBER	RESEARCH FUNCTION	SPACE ANALYSIS	GROUND ANALYSIS	WHOLE BLOOD	SERUM	PLASMA	URINE	PRESERVATIVE	VOLUME (ml)	CENTRIFUGE (042)	CRYOFREEZER (077B)	FREEZER (080)	REFRIGERATOR (083)	CLINICAL SIGNIFICANCE	CREW TIME (CM)	UTILIZ.
34C	BLOOD ELECTROLYTES		X		X				0.3	X		X		3	10m per	
35A	BLOOD pH, pCO_2, pO_2		X	X				HEP	0.5					3	min	
39A	THYROID FUNCTION								1.0	X	X	X		1	15m per	
	CHOLESTEROL		X		X				0.3	X	X	X		1	min	
	CPK (Creatine Phosphokinase)		X		X				0.2	X	X	X		1		X
	PBI (Protein Bound I_2)		X		X				0.3	X	X	X		1		
40D	BLOOD MORPHOLOGY		X	X					1drop					3	10m	
40D	CELL COUNT	X		X				EDTA	0.3					3	/ min	
69A	CARBOHYDRATE ANALYSIS (GLUC)		X		X				0.4	X	X	X		3		
336B	GLUCOSE, SERUM		X		X				0.2	X	X	X		3		
337B	PHOSPHATE, PLASMA		X			X		EDTA	0.5	X	X	X		1	15m	
339B	BILIRUBIN, PLASMA		X			X		EDTA	0.3	X	X	X		1	/ min	
417A	CHOLESTEROL (See also 39A)		X		X					X	X	X		2		
431A	BLOOD UREA NITROGEN (BUN)		X		X				0.3	X	X	X		3		
432A	URIC ACID		X		X				0.2	X	X	X		1		
174B	ENZYME ANALYSIS														30m	
408A	SGOT		X		X				0.2	X	X	X		3	/ min	X
409A	SGPT		X		X				0.2	X	X	X		3		X
434A	CPK (See also 39A)		X		X				0.2	X	X	X		3		X
435A	LDH and LDH ISOENZYMES		X		X				0.4	X	X	X		3		X
338B	ALKALINE PHOSPHATASE		X		X				0.2	X	X	X		1		X
442A	RBC ENZYME MEASUREMENT		X	X				HEP	0.5				X	1		
36C	BLOOD TOTAL PROTEIN		X		X				0.2	X	X	X		2	15m	
175B	AMINO ACID ANALYSIS		X		X				0.3	X	X	X		2	/min	
177B	PROTEIN ASSAY		X		X				0.3	X	X	X		2		
341C	IMMUNOGLOBULINS (See 177B)															
67A	LIPID ANALYSIS															
	LIPOPROTEIN ELECTROPHOR.		X		X				0.3	X	X	X		1		
	TRYGLYCERIDES		X		X				0.2	X	X	X		1		
	CHOLESTEROL (See 417A)															
333A	BLEEDING TIME (IVY)	X		X										3	20m	
334A	CLOTTING TIME (LEE WHITE)	X		X					0.5					3	/ min	
342A	PLASMA COAGULATION															
	PROTHROMBIN TIME		X			X		CIT	0.3	X			X	3		
	PARTIAL THROMBOPLASTIN TIME		X			X		CIT	0.2	X			X	3		
	QUANTITATIVE FIBRINOGEN		X			X		CIT	0.5	X			X	1		
429A	SERUM ADH		X		X				0.5	X	X	X		1	25m	X
430A	17-HYDROXYCORTICOSTEROIDS		X		X				0.5	X	X	X		1	/min	X
433A	BLOOD BICARBONATE (See 35A)															
436A	SERUM ACTH		X		X				0.5	X	X	X		1		
437A	TBPA		X		X				0.4	X	X	X		1		X
438A	HISTAMINE		X		X				0.5	X	X	X		1		X
439A	LYMPHOCYTE KAROTYPING		X	X				HEP	0.3				X	1		
440A	TRANSFERRIN (TIBC)		X	X				CIT	0.4				X	1		
441A	METHEMOGLODIN		X	X				HEP	0.2				X	1		
443A	COMPLEMENT TITRATION		X		X				0.5	X	X	X		1		
444A	TSH DETERMINATION		X		X				0.3	X	X	X		1	25m	
445A	BLOOD PARATHYROID HORMONE		X		X				0.4	X	X	X		1	/min	
445A	BLOOD GROWTH HORMONE LEVEL		X		X				0.6	X	X	X		1		
447A	SERUM CALCITONIN		X		X				0.3	X	X	X		1		
448A	INSULIN ASSAY		X		X				0.5	X	X	X		1		
449A	GLUCAGON ASSAY		X		X				0.4	X	X	X		1		
450A	5-HYDROXYINDOLE (5-HIAA) (SEROTONIN)		X		X				0.5	X		X		1		

Table 7-4. Function List and Technical Requirements, Biology Carry-On Payload — Small Vertebrates

	FUNCTION DATA	ANALYSIS		SAMPLE						COLLECTION		EQUIPMENT RUNTS			
INVENTORY NUMBER	RESEARCH FUNCTION	SPACE ANALYSIS	GROUND ANALYSIS	WHOLE BLOOD	SERUM	PLASMA	URINE	PRESERVATIVE	VOLUME (ml)	CENTRIFUGE (042)	CRYOFREEZER (077B)	FREEZER (080)	REFRIGERATOR (093)	CLINICAL SIGNIFICANCE	CREW TIME (min) LYO-PHILIZ.
34C	BLOOD ELECTROLYTES		X	X				0.3	X		X		3	10m per rat	
35A	BLOOD pH, pCO_2, pO_2		X	X			HEP	0.5					3		
39A	THYROID FUNCTION							1.0	X	X	X		1	15m per rat	
	CHOLESTEROL		X		X			0.3	X	X	X		1		
	CPK (Creatine Phosphokinase)		X		X			0.2	X	X	X		1		X
	PBI (Protein Bound I_2)		X		X			0.3	X	X	X		1		
40D	BLOOD MORPHOLOGY		X	X				Idro					3	10m /rat	
40D	CELL COUNT	X		X			EDTA	0.3					3		
69A	CARBOHYDRATE ANALYSIS (GLUC)		X		X			0.4	X	X	X		3		
336B	GLUCOSE, SERUM		X		X			0.2	X	X	X		3		
337B	PHOSPHATE, PLASMA		X			X	EDTA	0.5	X	X	X		1	15m /rat	
339B	BILIRUBIN, PLASMA		X			X	EDTA	0.3	X	X	X		1		
417A	CHOLESTEROL (See also 39A)		X		X				X	X	X		2		
431A	BLOOD UREA NITROGEN (BUN)		X		X			0.3	X	X	X		3		
432A	URIC ACID		X		X			0.2	X	X	X		1		
474B	ENZYME ANALYSIS													30m /rat	
408A	SGOT		X		X			0.2	X	X	X		3		X
409A	SGPT		X		X			0.2	X	X	X		3		X
434A	CPK (See also 39A)		X		X			0.2	X	X	X		3		X
435A	LDH and LDH ISOENZYMES		X		X			0.4	X	X	X		3		X
438B	ALKALINE PHOSPHATASE		X		X			0.2	X	X	X		3		X
442A	RBC ENZYME MEASUREMENT		X	X			HEP	0.5				X	1		
06C	BLOOD TOTAL PROTEIN		X		X			0.2	X	X	X		2	15m /rat	
175D	AMINO ACID ANALYSIS		X		X			0.3	X	X	X		2		
177B	PROTEIN ASSAY		X		X			0.3	X	X	X		2		
341C	IMMUNOGLOBULINS (See 177B)														
67A	LIPID ANALYSIS														
	LIPOPROTEIN ELECTROPHOR.		X		X			0.3	X	X	X		1		
	TRYGLYCERIDES		X		X			0.2	X	X	X		1		
	CHOLESTEROL (See 417A)														
333A	BLEEDING TIME (IVY)	X		X									3	20m /rat	
334A	CLOTTING TIME (LEE WHITE)	X		X				0.5					3		
342A	PLASMA COAGULATION														
	PROTHROMBIN TIME		X			X	CIT	0.3	X			X	3		
	PARTIAL THROMBOPLASTIN TIME		X			X	CIT	0.2	X			X	3		
	QUANTITATIVE FIBRINOGEN		X			X	CIT	0.5	X			X	1		
429A	SERUM ADH		X		X			0.5	X	X	X		1	25m /rat	X
430A	17-HYDROXYCORTICOSTEROIDS		X		X			0.5	X	X	X		1		X
433A	BLOOD BICARBONATE (See 35A)														
436A	SERUM ACTH		X		X			0.5	X	X	X		1		
437A	TBPA		X		X			0.4	X	X	X		1		X
438A	HISTAMINE		X		X			0.5	X	X	X		1		X
439A	LYMPHOCYTE KAROTYPING		X	X			HEP	0.5				X	1		
440A	TRANSFERRIN (TIBC)		X	X			CIT	0.4				X	1		
441A	METHEMOGLOBIN		X	X			HEP	0.2				X	1		
443A	COMPLEMENT TITRATION		X		X			0.5	X	X	X		1		
444A	TSH DETERMINATION		X		X			0.3	X	X	X		1	20m /rat	
445A	BLOOD PARATHYROID HORMONE		X		X			0.4	X	X	X		1		
446A	BLOOD GROWTH HORMONE LEVEL		X		X			0.4	X	X	X		1		
447A	SERUM CALCITONIN		X		X			0.3	X	X	X		1		
448A	INSULIN ASSAY		X		X			0.5	X	X	X		1		
449A	GLUCAGON ASSAY		X		X			0.4	X	X	X		1		
450A	5-HYDROXYINDOLE (5-HIAA) (SEROTONIN)		X		X			0.5	X		X		2		

Table 7-5. Function List and Technical Requirements, Cells/Tissues Carry-On Payload

FUNCTION DATA		ANALY.		SAMPLE							COLLECTION			STORAGE		
INVENTORY NUMBER	RESEARCH FUNCTION	SPACE ANALYSIS	GROUND ANALYSIS	CELLS, BACTERIAL	CELLS, PLANT	CELLS, MAMMALIAN	TISSUES, PLANT	TISSUES, MAMMALIAN	CELLS, SUBCULTURE	TISSUES, BIOPSY	BIOLOGICAL FLUIDS	INCUBATE	PLACE IN TRANSPORT MEDIA	REFRIGERATE	FREEZE	LYOPHIL-IZE
26	Liquid Volume Measurements	X								X						
29 A	Mass Measurements	X					X	X								
32 B	Specimen Status Observation	X		X	X	X	X	X		X						
35 A	pH, pCO_2, pO_2 Measurement		X	X	X	X				X				X		
77	Microscopy, Gnl. (Part of 32B)	X		X	X	X	X	X								
84 A	Organism Subculturing	X		X	X	X										
86 B	Bacterial Colony Counting	X		X												
103D	Bacterial Cell Counting	X		X												
141A	Airparticulate Sampling	X														
142A	Microbiological Sampling	X		X							X	X				
226B	Cells and Tissues Population Density	X		X	X	X	X	X								
372A	Fungal Culturing	X									X	X				
	BIOCHEMICAL STUDIES															
155B	Phosphates		X				X	X		X					X	
156B	Creatine and Creatinine		X					X		X					X	
174B	Enzyme Assay															
408A	SGOT		X					X		X	X				X	
409A	SGPT		X					X		X	X				X	
434A	CPK		X					X		X	X				X	
435A	LDH		X					X		X	X				X	
	Aldolase		X				X	X		X					X	
	Carboxylase (Ribulose PO_4)		X				X			X					X	
338A	Alkaline Phosphatase		X				X	X		X					X	
175B	Amino Acid Assay		X	X	X	X	X	X	X	X	X				X	X
177B	Protein Assay (36C-Total Prot)		X	X	X	X	X	X	X	X	X				X	X
180B	Plant Hormones		X		X		X		X	X					X	
	Protoporphyrins		X		X		X								X	
	Phycocyanin		X		X		X								X	
336	Glucose		X		X	X	X	X			X				X	
337	Phosphate		X		X	X	X	X		X	X				X	
34C	Electrolytes (Na, K, Mg, Cl)		X		X	X	X	X			X				X	
340	Globulins		X			X		X							X	
341	Immunoglobulins		X			X		X							X	
453A	Calcium		X		X	X	X	X							X	
454A	Mucoproteins		X			X		X							X	
455A	Pyrophosphates		X			X		X							X	

Table 7-6. Carry-On Payload Equipment List, Biomedical Research

CARRY ON PAYLOAD EQUIPMENT LIST
BIOMEDICAL RESEARCH

EI NO.	EQUIPMENT ITEM NAME	QUANT.	HUM*	BRS*	WT. LB	POWER	VOL. FT^3	OFF-SHELF ITEM	NOTES
	COMMON USE EQUIPMENT								
	Holding Unit (Enclosure only)	1	X		60	50	6.6		
096	Glove Box	1	X		25	30	1		
056	Cryosystem	1		X	19	100	0.5	X	Cryobath power supply Cole-Parmer Instrument Co.
077B	Cryofreezer	1		X	5.5		0.5	X	
080	Freezer, General Purpose	1		X	30	50	1.6	X	
083	Refrigerator	1		X	25	50	1.5	X	
106	Kit, Hematology	1	X		10		0.5	X	Vacutainers, slides, needles
110C	Kit, Physiology	1	X		5		0.5	X	Biopacks, electrodes, Xducers
042	Centrifuge, Micro	1		X	18	50	0.5	X	Beckman Spinco
118	Lyophilizer	1		X	3		0.4	X	Use with space vacuum.
	FPE OR EXPERIMENT SPECIFIC EQUIPMENT								
064	ECG Coupler	1	X		0.1	1	0.001	X	
076F	Flowmeter, Water Manifold	1	X		0.1	1	0.001	X	
143E	Blood Pressure Cuff	2		X	2.0		0.1	X	
143G	Coupler, Blood Pressure	2		X	0.2	2	0.02	X	
126B	Microphone (cardiac)	1		X	0.1		0.001	X	
126C	Microphone Amplifier, Cardiac	1		X	0.1	10	0.001	X	
143F	Cuff Pump, Blood Pressure	2		X	0.1		0.01	X	
116	Log Books, Daily Record	3		X	3.0		0.05	X	
	ELECTROPHYSIOLOGY PACKAGE								
065E	Electrophysiology Monitor	1	X		100	50	3.0		
182J	Coupler, Vectorcardiogram	1	X		0.1	1	0.04		
140	Coupler, Phono/Vibrocardiogram	1	X		0.2	1	0.01		
104E	Coupler, Impedance Cardiogram	1	X		0.2	1	0.01		
076K	Flowmeter, Doppler Blood Flow	1	X		1.0	1	0.1		
076G	Flowmeter, Ultrasonic Blood Flow	1	X		0.4		0.5		
	INTEGRATED SUPPORT PACKAGE								
006	Air Particle Sample Collector	1	X		6		0.3	X	Modified Anderson Sampler
110	Kit, Microbiology	1	X		5		1.0	X	
141	Plastic Bag Dispenser/Sealer	1	X		20		2.0		
	TOTALS (WT./PWR./VOL.)				334	400	20		

* Indicates Equipment Item is either contained in the BRS (Bioresearch Support Module) or the HUM (Holding Unit Module).

Table 7-7. Carry-On Payload List, Small Vertebrates

CARRY ON PAYLOAD EQUIPMENT LIST
SMALL VERTEBRATES

EI NO.	EQUIPMENT ITEM NAME	QUANT.	HUM*	BRS*	WT. LB	POWER	VOL. FT^3	OFF-SHELF ITEM	NOTES
	COMMON USE EQUIPMENT								
103	Holding Unit (small vertebrates)	1	X		60	50	6.6		
096	Glove Box	1	X		25	30	1		
056	Cryosystem	1		X	19	100	0.5	X	Cryobath power supply Cole-Parmer Instrument Co.
077B	Cryofreezer	1		X	5.5		0.5	X	
080	Freezer, General Purpose	1		X	30	50	1.6	X	
083	Refrigerator	1		X	25	50	1.5	X	
106	Kit, Hematology	1	X		10		0.5	X	Vacutainers, slides, needles
110C	Kit, Physiology	1	X		5		0.5	X	Biopacks, electrodes, xducers
042	Centrifuge, Micro	1		X	18	50	0.5	X	Beckman Spinco
118	Lyophilizer	1		X	3		0.4	X	Use with space vacuum.
	FPE OR EXPERIMENT SPECIFIC EQUIPMENT								
030A	Cage, Rat (Part of 103)								
	Feeder, Pellet Dispenser	8	X						
	Pads, Urine/Feces (Pkg. 16)	2	X						
118D	Manifold, Organism Watering	1	X		10		1.0		
076H	Flowmeter Coupler, Water Manifold	1	X		0.1	1	0.04		
076F	Flowmeter, Water Manifold	1	X		0.8	8	0.08		
032	Camera, Cine	1		X	8		0.3	X	
037	Camera, Video, B&W	1		x	10	15	0.1	X	
064	ECG Coupler	1		X	0.1	1	0.01	X	
110B	Kit, Organism Holding/Management	1	X		20		1		
114A	Kit, Microdissection	1	X		1		0.1	X	
134A	Patchboard System (part of Data Mgmt)	1	X		3		0.4		
126G	Monitor, Video	1		X	20	50	1	X	
143E	Pressure Cuff and Transducer	8	X		0.5		0.005	X	
143G	Coupler, Blood Pressure	1	X		0.1	1	0.001	X	
180	Timer, Event	1		X	0.5	1	0.01	X	
126B	Microphone	1		X	0.1		0.001	X	
126C	Microphone Amplifier	1		X	0.1	10	0.01	X	
	Small Vertebrate Environmental Control and Life Support System		X		47	55	2.1		
	TOTAL WT., POWER, AND VOLUME				322	462	19.6		

*Indicates Equipment Item is either contained in the BRS (Bioresearch Support Module) or the HUM (Holding Unit Module).

Table 7-8. Carry-On Equipment List, Cells and Tissues (Mammals, Invertebrates, and Plants)

CARRY ON PAYLOAD EQUIPMENT LIST
CELLS AND TISSUES
(Mammalian, Invertebrate and Plant)

EI NO.	EQUIPMENT ITEM NAME	QUANT.	HUM*	BRS*	WT. LB	POWER	VOL. FT^3	OFF-SHELF ITEM	NOTES
	COMMON USE EQUIPMENT								
098A	Holding Unit (Cells/Tissues)	1	X		60	50	6.6		
096	Glove Box	1	X		25	30	1		
056	Cryosystem	1		X	19	100	0.5	X	Cryobath power supply
077B	Cryofreezer	1		X	5.5		0.5	X	Cole-Parmer Instrument Co.
080	Freezer, General Purpose	1		X	30	50	1.6	X	
083	Refrigerator	1		X	25	50	1.5	X	
106	Kit, Hematology	1	X		10		0.5	X	Vacutainers, Slides, Needles
110C	Kit, Physiology	1	X		5		0.5	X	Biopacks, electrodes, xducers
042	Centrifuge, Micro	1		X	18	50	0.5	X	Beckman Spinco
118	Lyophilizer	1		X	3		0.4	X	Use with space vacuum.
	FPE OR EXPERIMENT SPECIFIC EQUIPMENT								
114A	Kit, Microdissection	1	X		10		1	X	Small tools
032	Camera, Cine	1		X	8		0.03	X	
052	Counter, Cell	1	X		20	40	2.0	X	Modified Coulter Counter
054	Counter, Colony, Manual	1	X		4	40	0.2	X	Modified Quebec Counter
108	Kit, Histology	1	X		5		1.0	X	
111	Kit, Plant Tools	1	X		1.0		0.1	X	
122	Mass Measurements, Micro	1		X	10	15	0.5		
124	Media, Prepared, Assorted (pkg.)	1	X		10		0.5	X	Culture media
126A	Microscope, Dissecting	1		X	10	30	0.5	X	
165	Sterilizer, Small Tool	1		X	2	100	0.1	X	Bactecinerator
001	Accelerometer	1	X		0.001	0.2	0.001	X	
001A	Coupler, Accelerometer	1	X		2.0	10	0.001	X	
	INTEGRATED SUPPORT PACKAGE								
110	Air Particle Sample Collector	1	X		6		0.03	X	Modified Anderson Sampler.
141	Plastic Bag Dispenser/Sealer	1	X		20		2.0		
	Cells and Tissues Environmental Control and Life an Support System	1	X		TBD	TBD	TBD		
	TOTALS (WT./PWR./VOL.)				314	565	22.5		

*Indicates Equipment Item is either contained in the BRS (Bioresearch Support Module) or the HUM (Holding Unit Module).

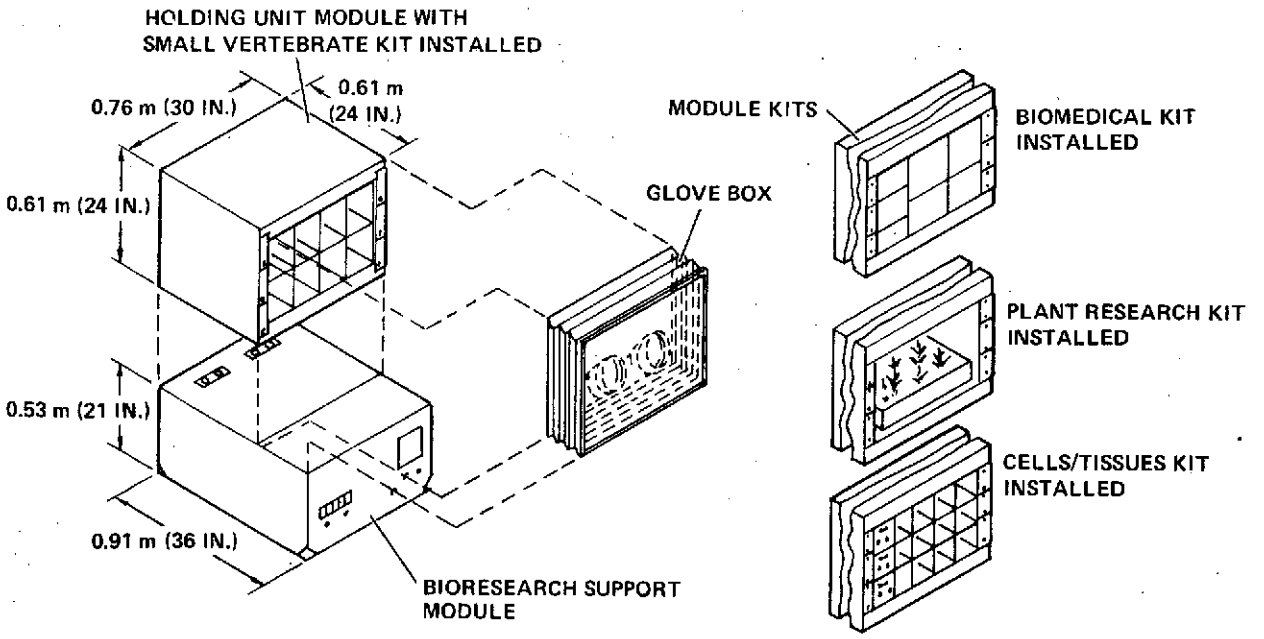


Figure 7-1. Conceptual Carry-On Laboratory, Biology and Biomedicine

The HUM is designed to accommodate the FPE-specific kits. For the biological FPEs, these would contain the living organisms on which a variety of experiments would be performed. For the biomedical FPEs, additional instrumentation for obtaining biomedical measurements on man would be included. The HUM also contains some of the common-use and experiment specific equipment, and interfaces with a collapsible glove box to minimize contamination of the crew compartment and the experiments.

The Bioresearch Support Module contains the majority of the equipment required to collect and preserve the test specimens and experimental data.

7.3 MAN-SYSTEMS INTEGRATION (MSI) CARRY-ON LABORATORY

The conceptual design of the MSI Carry-On Laboratory for Man-System Integration was based on a slightly different approach, as discussed below.

7.3.1 RESEARCH AREA OF INTEREST. Carry-on laboratories on the early shuttle flights, while of little use in behavorial investigations due to limited mission durations, could generate considerable useful data on man's ability to perform tasks of potential application on current and future manned space systems. Some of the research areas of interest are the effects of weightlessness on man's cargo-handling capabilities (mass limits, techniques), maintenance and repair capabilities (component replacement, on-site repair), and assembly and deployment capabilities. Other research areas are the impact on these skills of pressure-suit constraints (limited reach and mobility, suit

torques), EVA environmenta; effects (harsh lighting, vacuum), task completion via teleoperators, and the possible synergistic effects of these constraints.

For the current study, NASA directed research in the maintenance and repair category. Of particular importance will be visual records of the experimental tasks for error analysis, task time determinations, documentation of zero-g techniques, and comparison with ground-based simulations.

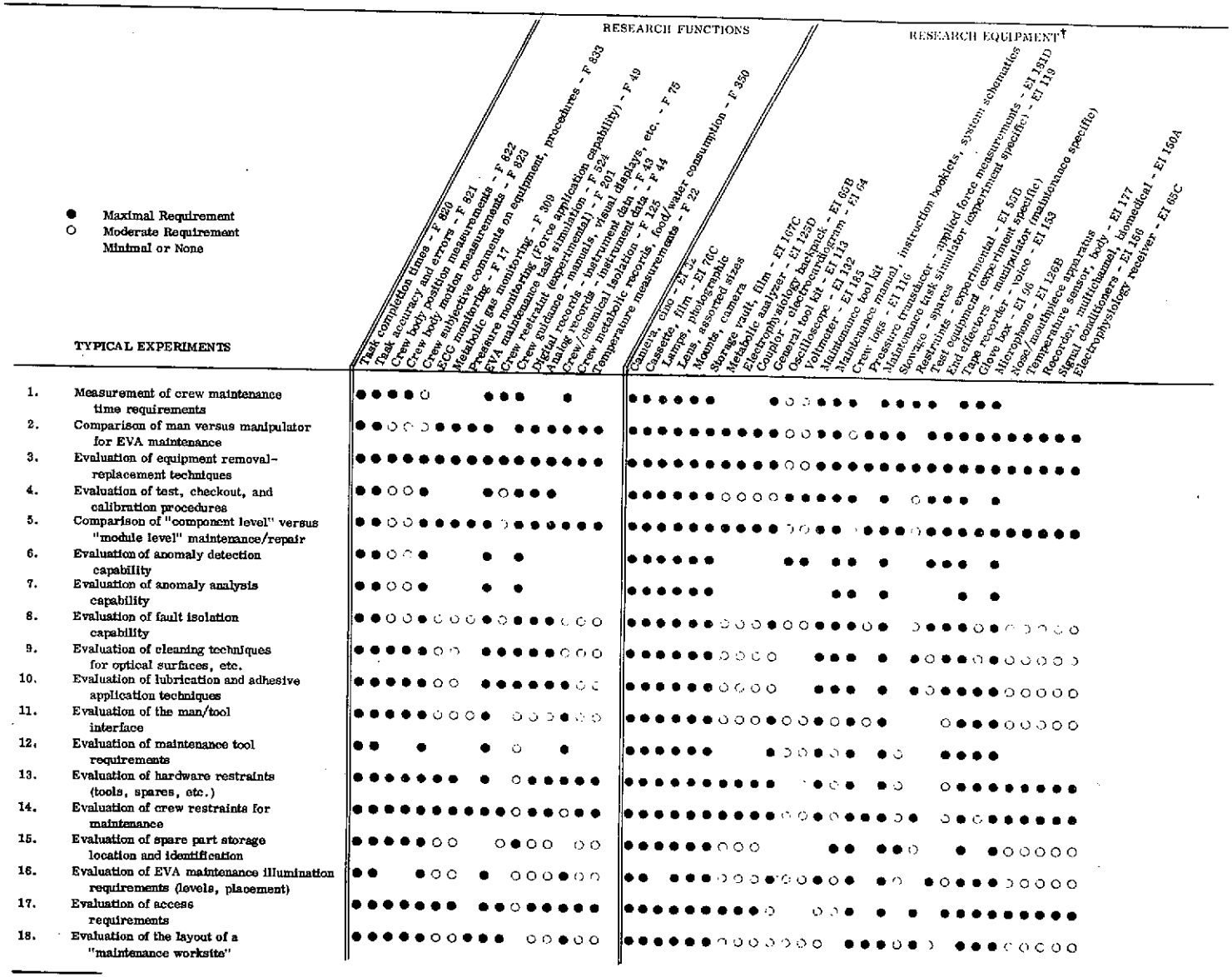
7.3.2 CONCEPTUAL DESIGN. The design analysis for the MSI Carry-on Laboratory was based on a list of typical experiments provided by NASA. The list was expanded as the result of a brief literature search to ensure that a representative sample was used as the basis for equipment selection. Each experiment was analyzed, and the functions were identified from the Life Sciences Functions Inventory that were required to perform the experiment. The requirement for these functions was rated on a three-step scale from maximal to minimal. The equipment required by these functions was identified and similarly rated. Figure 7-2 lists these typical experiments in the maintenance and repair category juxtaposed with their required research functions and equipment items. The commonality of some of the equipment items across the list of typical experiments can be easily seen. This procedure identified the equipment required on most of the maintenance and repair experiments. These items compose the carry-on module designated the Maintenance Common Module. Equipment that was more experiment-specific was placed in the Simulator Module.

Figure 7-3 illustrates the conceptual design of the Maintenance and Repair Research Laboratory. The Simulator Module consists of an experiment(s) specific test bed (task simulator) and its supporting equipment. The Maintenance Test Bed would be the critical component for each series of selected experiments. It could contain, for example, a series of representative fluid control valves to which access is limited by various sizes of apertures, or a series of black boxes (electronic components) designed to function in various degraded modes as required by the experiment, and which require selected techniques for their removal and replacement or on-the-spot repair. The Maintenance Support Component would contain experiment-specific support equipment. For example, this would include the required spare components in a component removal and replacement study, or the special adhesives, lubricants, and unique support tools in an adhesive and lubricant applications study.

The Maintenance Common Module contains equipment items that will remain relatively unchanged regardless of the nature of the experiment. It consists of three primary components:

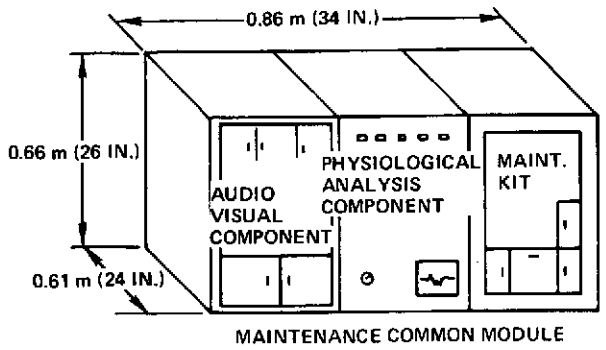
a. The audio-visual component containing cameras, film cassettes, and floodlights for visual records, and microphones and tape recorders for audio records.

b. The physiological analysis component containing the instrumentation to monitor subject energy expenditure.



† Research equipment. Operational equipment such as EVA support equipment (space suits, etc.), the shuttle remote manipulator, crew restraints, etc., are not considered here.

Figure 7-2. Functional and Equipment Requirements for Typical Maintenance Experiments



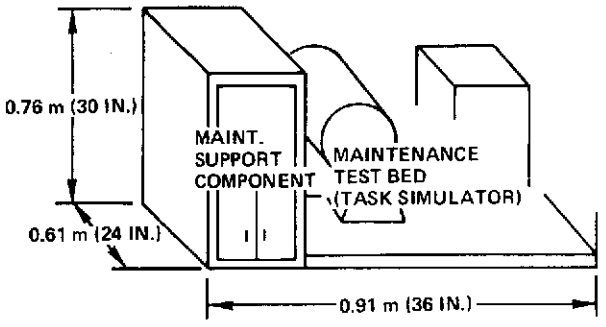


Figure 7-3. Conceptual MSI Carry-on Laboratory, Maintenance and Repair Research

c. The basic tool kits that support maintenance and repair activities. Primarily, these include a general-purpose tool kit and a maintenance-specific tool kit.

Depending on the nature of the specific Maintenance Test Bed and supporting spares, test equipment, and tools, a number of maintenance experiments could be performed on any given mission. In addition, the common nature of the Maintenance Common Package would allow experiments from several classes of MSI experiments to be conducted on one mission. As an example, experiments could be conducted in both the Maintenance and Repair and Cargo Handling categories. The Simulator Module could be so designed that its components serve as test masses of various sizes for cargo handling experiments after the maintenance experiments are completed. The Maintenance Common Package could provide the necessary instrumentation.

7.4 LIFE SUPPORT/PROTECTIVE SYSTEMS (LS/PS) CARRY-ON LABORATORY. The conceptual design of the LS/PS Carry-on Laboratory was a modification of an existing design, as discussed in the following paragraphs.

7.4.1 RESEARCH AREA OF INTEREST. A NASA program has been underway since 1967 to study the effects of reduced gravity on the performance of life-support system components. This program, Gravity Sensitivity Assessment Criteria Study (NASA CR-66945), initially developed analytical models to predict low-gravity performance phenomena, and has now begun the design of test units for actual zero-g testing.

The experiment system concept illustrated in Figure 7-4 is a full-scale experiment test system that could be part of a space laboratory. Its basic configuration consists of two modules - one to control the experiment test parameters, and the other to contain the component or unit being tested.

The conceptual designs allow for testing various components with the same experiment test system. The areas of interest that could be investigated include:

a. Nucleate boiling.

b. Diffusion convection.

c. Film stability and transport.

d. Inertial separation.

e. Convection heat transport.

f. Flow regime characteristics.

The task in the LS/PS area was to determine if this existing conceptual design could be modified to be compatible with the Carry-on Laboratory requirements and constraints.

7.4.2 CONCEPTUAL DESIGN. The experiment test system concept shown in Figure 7-4 was reduced in size and capability for the Carry-on Laboratories. Figure 7-5, the Experiment Control Console, provides display and control functions for:

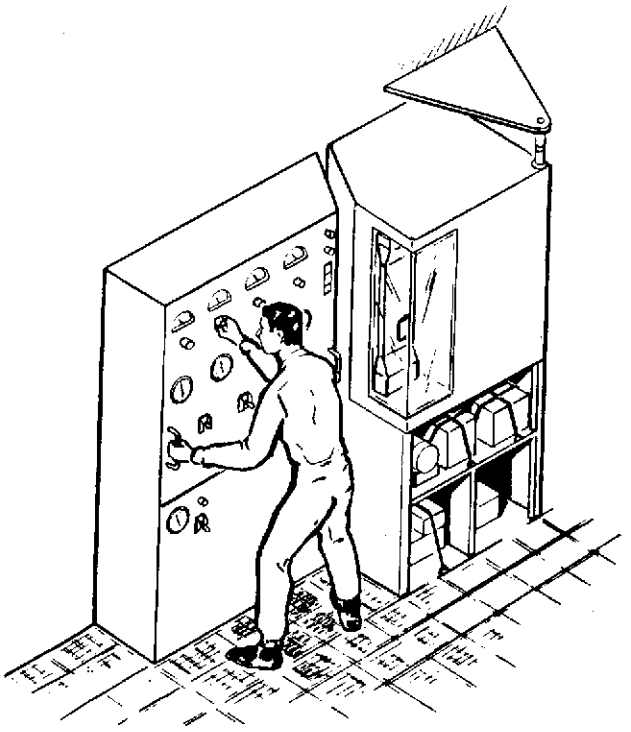


Figure 7-4. LS/PS Experiment System

a. Liquid/gas flow rates.

b. Operating pressures.'

c. Motor/pump(s) speed.

d. Sensor(s) operating mode(s).

e. Time code and event parameters.

f. Operating temperatures.

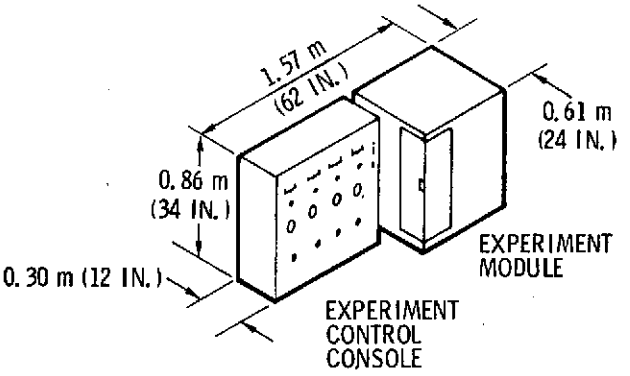


Figure 7-5. Conceptual LS/PS Carry-On Laboratory

The Experiment Module Provides experiment support functions for:

a. Liquid/gas supply.

b. Transport.

c. Quality control.

d. Storage.

e. Thermal Control

f. Metering.

g. Mixed phase flow engines.

The reduced LS/PS Carry-on Laboratory approximately meets the NASA constraints, as discussed in the following section.

7.5 SUMMARY OF THE CARRY-ON LABORATORY

As Table 7-9 indicates, the key design parameters of the Carry-on Laboratories, weight, power, and volume, are in most cases within the tentative NASA constraints.

Table 7-9. Carry-On Laboratory Data Summary

FPE	NO. OF PACKAGES	WEIGHT kg (LB.)	POWER (WATTS)	VOLUME m^3 CU. FT.
MEDICAL RESEARCH	2	152 (334)	400	0.566 (20)
VERTEBRATE RESEARCH	2	150 (332)	462	0.555 (19.6)
CELLS & TISSUES RESEARCH	2	142 (314)	565	0.637 (22.5)
PLANT RESEARCH	TBD	TBD	TBD	TBD
INVERTEBRATE RESEARCH	TBD	TBD	TBD	TBD
LIFE SUPPORT & PROTECTIVE SYSTEMS	2	159 (350)	725	0.637 (22.5)
MAN-SYSTEM INTEGRATION	2	136 (300)	433	0.557 (19.7)

The volumes are less than the 0.85 m^3 (30 cu. ft.) constraint and the peak powers, with the exception of life support and protective systems and probably the plant research laboratory, are close to the 500 watt constraint. With a ten percent addition for rack weight, the heaviest laboratory is approximately 175 kg (385 lb). Although not considered in the current study, the plant and invertebrate research laboratories probably fall very close to the tentative constraints as well, since they use must of the same equipment as the other biological laboratories.

SECTION 8

LABORATORY SCHEDULE AND COST ESTIMATING STUDIES

This section presents the results of the laboratory scheduling and costing activities. It includes discussions of the laboratory development schedules, their basis, and their compatibility with the general mission model. It also includes a discussion of the cost analysis approach, the resulting equipment cost estimates, and the resulting laboratory funding schedules (cost distributions).

Most of the material discussed here is based on independent laboratory development; that is, one laboratory (the Shared 7-Day, the Dedicated 7-Day, or the Dedicated 30-Day) will be selected for development — not all three. Evolutionary development of the laboratory — that is, the development and use of the Shared Laboratory for some initial time period followed by the use of the Dedicated (7-Day) Laboratory, and finally the use of the Dedicated (30-Day) Laboratory, with a corresponding reduction in the development costs of the latter two, is highly probable, however. To estimate laboratory costs for this evolutionary concept, it was necessary to assume a growth model, as discussed in paragraph 8.2.3.

8.1 LABORATORY DEVELOPMENT SCHEDULES

Laboratory development is paced by the development of the equipment units (EU) within each laboratory, which in turn is paced by the development of each equipment item (EI) within each EU. The development time for each EI has been estimated by Convair Aerospace technical specialists and/or outside consultants, based on the complexity of the EI and the difficulty of its manufacture. The development time for each EU was assumed to be the same as the longest development time of any of its component EIs.

To use the same assumption at the payload level — that is, payload development time would be the same as the longest EU development time — is not acceptable for several reasons. First, it is desirable to minimize annual funding peaks. Assuming all EUs will be developed within the development time span of the longest EU would create unnecessarily high funding peaks that could be reduced considerably by a staggered development schedule. Second, it is desirable to initiate development of the more complex EUs first to provide time for solving unanticipated technical problems without impacting the laboratory development schedule. This would not be the case if all the EUs were being developed at the same time.

To define an appropriate development schedule, it was necessary to establish EU development priorities. These priorities are based on the following assumptions:

a. EUs containing high development risk (pacing) equipment will be initiated at an early date (e.g., holding units). Pacing equipment are those items that closely interface with, and are configuration drivers for, a number of other equipment items.

b. Common use (CORE) EUs have a high development priority with the exception of the maintenance and storage units. The latter units are easily constructed and do not require early development.

c. Support EUs will be initiated only after their key EUs are well defined (development 50 percent complete). The key EUs are the basic holding and FPE measurement units, such as EU 40 (Small Vertebrate Holding Unit) and EU 91 (MSI Measurements Unit). Their support EUs — EU 42 (Vertebrate Research Support Unit) and EU 12 (Biomedical/Behavioral Research Support Unit), respectively — contain the equipment necessary to support the primary holding and measurement functions.

d. EUs whose configuration might be altered by the Skylab experimental results will be delayed until those results have received sufficient analysis to indicate configuration impact.

A representative equipment unit development schedule based on the foregoing assumptions is illustrated in Figure 8-1. Two years are provided between completion of the

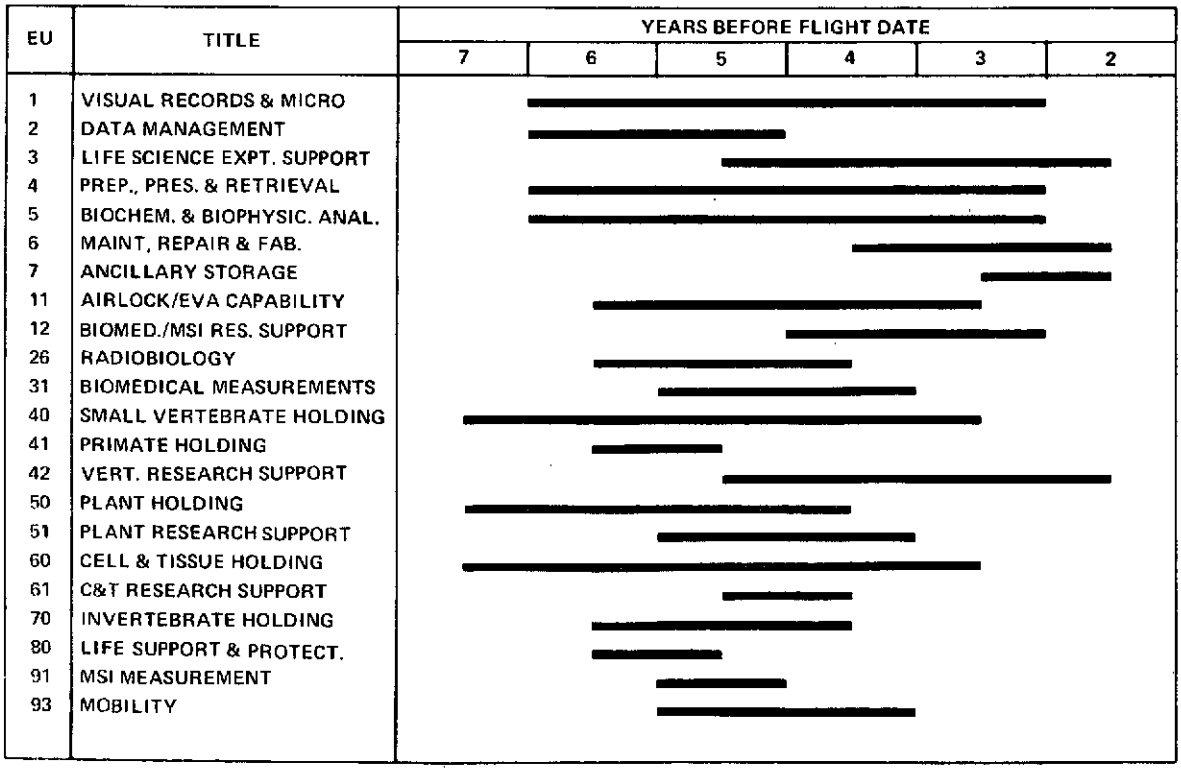


Figure 8-1. Sample EU Development Schedule 7-Day Laboratory

equipment units and the flight date to allow for principal investigator familiarization, baseline testing, etc. This schedule is compatible with the typical mission model presented in Figure 8-2. If the development of the first EUs is initiated in July 1973, the laboratory equipment would be available in time for a mid-1980 launch date.

8.2 COST ANALYSIS

An overview of the cost analysis approach is illustrated in Figure 8-3. As a starting point in the cost analysis, the EI costs developed during Task A and B were reviewed and updated with the most recent cost information available. The costs of the approximate 200 EIs were first listed in order from highest to lowest cost to determine the high poles and questionable estimates. With the EI costs so identified, the updating was concentrated on these areas. Secondly, the cost distribution data were calculated for each EI, EU, and laboratory based on the NASA idealized cost distribution guidelines (see paragraph 8.2.2). These cost distributions (funding schedules) were plotted as funding rate curves and cumulative cost curves. The third step involved the estimate of the laboratory specific subsystem costs for the organism ECS. The final step involved the combining of the EU cost distributions and organism ECS costs with certain integration, maintenance, and spare cost factors. The sum of these three major elements was the total laboratory funding requirements.

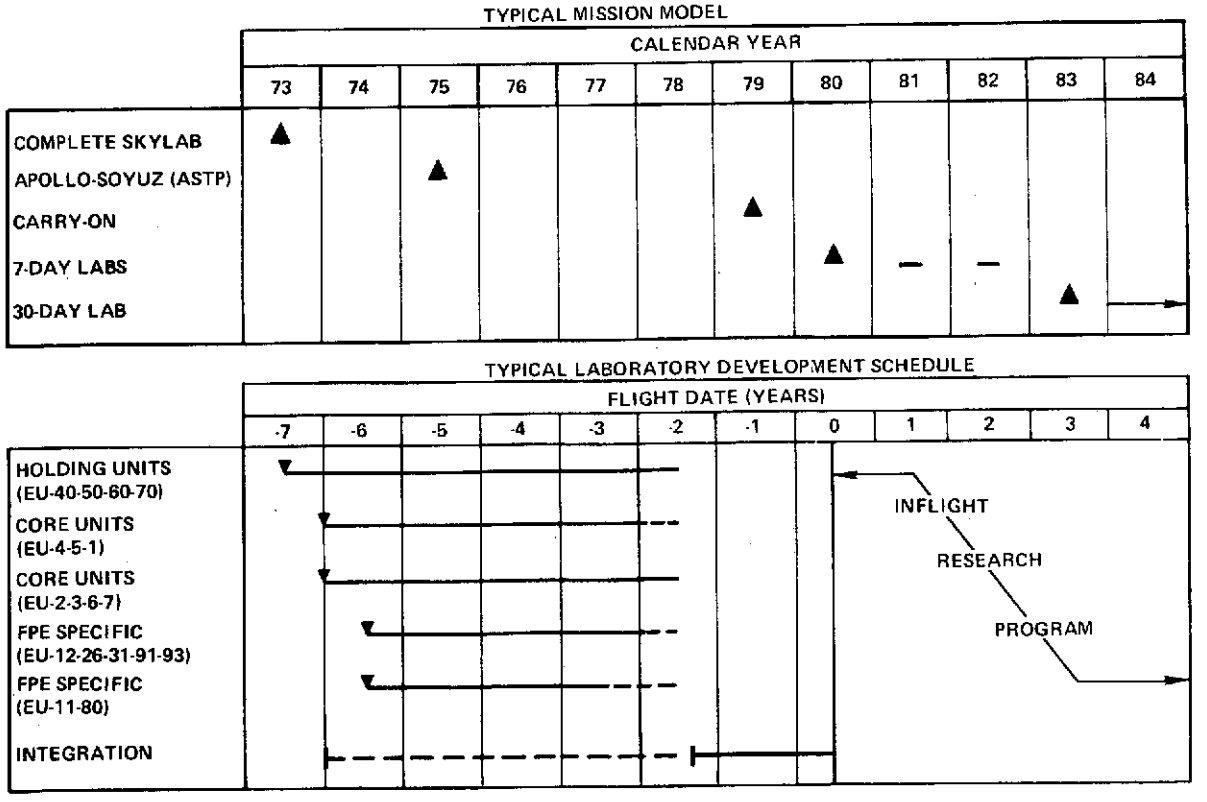


Figure 8-2. Life Sciences Laboratory Guideline Schedules

8.2.1 REVIEW OF TASK A AND B COST ESTIMATING APPROACH. The laboratory funding schedules were based on the EI cost estimates from Task A and B. Therefore, a review of this cost estimating approach is necessary to fully understand how the schedules were developed.

During Task A and B, an estimate of the development and unit costs for each of the 382 EIs in the equipment inventory was made by Convair Aerospace costing and technical specialists. These estimates were based on quotes from manufacturers and vendors, commercial catalog listings, and in-house sources. The specialists were guided by their knowledge of the extensive analysis and testing required by NASA specifications before a piece of experimental hardware could be considered flight qualified. (An example of these specifications is the Experiment General Specification for Hardware Development issued by the Office of Manned Space Flight for the Apollo Applications Program in 1969. Its purpose is to provide guidelines for the development of experiment hardware at minimum cost within the constraints of crew safety and mission success.) Average cost factors were calculated that related average development cost to unit cost and average unit cost to commercial cost. These were used as guidelines in developing later cost estimates and to double check existing estimates. In this way, extreme values were identified for review.

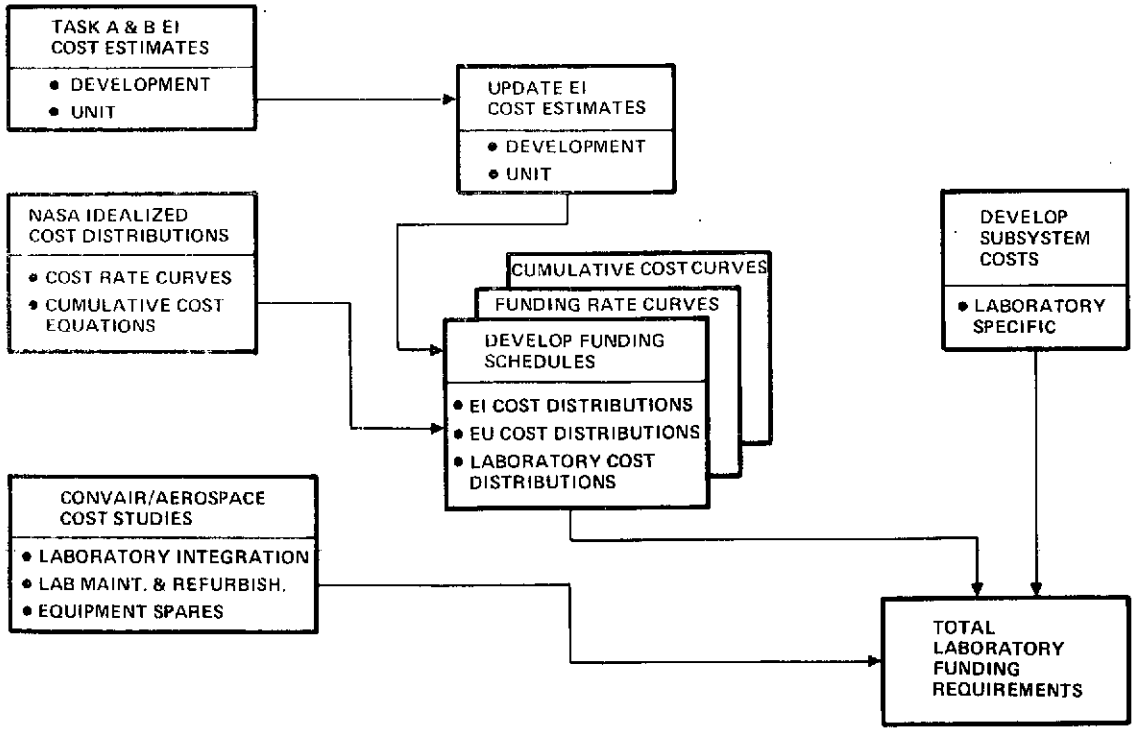


Figure 8-3. Cost Analyses Overview

The EI cost estimates were verified against historical data by a parametric analysis. The parameter used as the basis for the comparative analysis was equipment weight, which has been shown to be highly correlated with equipment cost. Each EU was grouped into one of ten categories by type of equipment on the expectation that items within each group would exhibit similar cost trends. A least-squares regression line was calculated for all of the equipment in selected categories and compared with historical data for the same category. This comparison provided a measure of the validity of our cost estimating approach. As an example, the regression line for the generic electronic/electrical category is plotted in Figure 8-4. This category contains the largest EI group in the Life Sciences inventory. Also drawn on the graph are curves representing historical spacecraft, aircraft, and commercial ground equipment costs for this category of equipment. The Life Sciences Laboratory equipment costs fall below spacecraft equipment costs by a factor of two and above aircraft costs by a similar factor. This indicates that the Task A and B cost estimating approach was reasonable.

8.2.2 CALCULATION OF FUNDING SCHEDULES. Equipment development and unit costs were updated at the beginning of this study phase where current cost information was available. These updated costs are tabulated by EU in Volume III, Appendix I and an example of those tables is shown in Table 8-1. These estimates were used to calculate EU and laboratory funding schedules (cost distributions). The cost distribution of

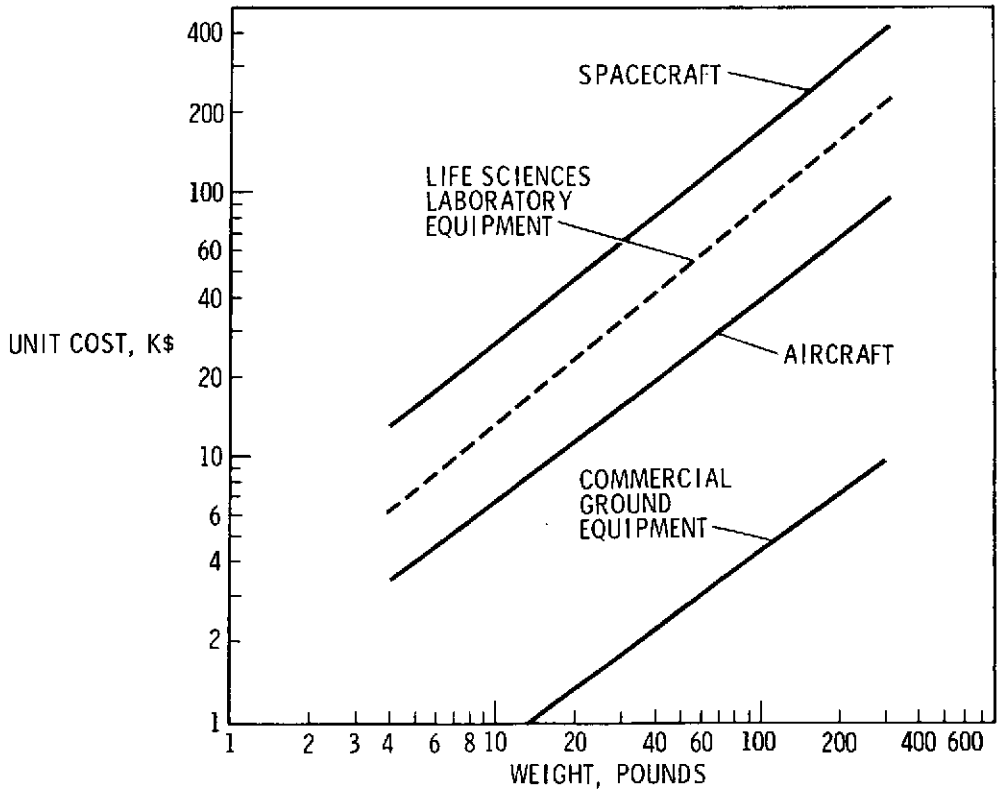


Figure 8-4. Sample Results of EI Cost Verification — Regression Lines for Electronic/Electrical EIs

Table 8-1. Example of Summary Cost Table EU 4 — Preparation, Preservation and Retrieval Unit

EQUIPMENT IDENTIFICATION		DEVELOPMENT		SHARED SORTIE (7 DAYS)				DEDICATED SORTIE (7 DAYS)				DEDICATED SORTIE (30 DAYS)				COMMERCIAL COSTS
No.	Title	Type	Time (Yrs)	Dev. Cost $K	Unit Cost $K	No. Req.	Total Cost $K	Dev. Cost $K	Unit Cost $K	No. Req.	Total Cost $K	Dev. Cost $K	Unit Cost $K	No. Req.	Total Cost $K	
14	ANESTHETZR INVERT	Remfg	1	35	5	1	40	35	5	4	55	35	5	10	85	
18	BENCH, LAM FLO	SRT	4	2000	25	1	2025	2000	25	1	2025	2000	25	1	2025	1600.00
18A	BENCH LINERS, LFB	SRT	2	100	1	10	110	100	1	10	110	100	1	40	140	
18B	BENCH INSERT - RADIOC	SRT	2		6	1	6		6	1	6		6	1	6	
41	CENTRIF FRIG HI SPD	Repack	2			0	0			0	0	175	25	1	200	3100.00
42	CENTRIF MICRO	Repack	2	75	5	1	80	75	5	1	80	75	5	1	80	200.00
44	CHEMICALS	Redesign	1	100	10	1	110	100	10	1	110	100	10	3	130	1000.00
44A	CHEMICALS - RADIOACTIVE	Minimal	0	0	10	1	10	0	10	1	10	0	10	3	30	1000.00
48	CLEANR, VACUUM	Redesign	3	200	50	1	250	200	50	1	250	200	50	1	250	300.00
63G	DEIONIZER PURE WATER	Redesign	3			0	0	100	15	1	115	100	15	1	115	173.00
70	ELECTROPHRSIS APPAR	Repack	1			0	0			0	0	50	5	1	55	887.00
77B	FREZR, CRYO	Redesign	3			0	0	500	25	1	525	500	25	2	550	2500.00
80	FREZR, GEN	Redesign	2	50	5	1	55	50	5	1	55	50	5	1	55	235.00
81	FREEZ, LO TEMP	Redesign	2			0	0			0	0	200	10	1	210	1675.00
83	FRIG	Redesign	2	50	5	1	55	50	5	1	55	50	5	1	55	235.00
97A	HEMATOCRT, ELECTRNIC	Remfg	1			0	0	40	5	1	45	40	5	1	45	258.00
105	KIT - BENCH CHEM ANAL	Repack	2	100	10	1	110	100	10	1	110	100	10	1	110	300.00
106	KIT - HEMATOLOGY	Remfg	1	7	1	1	8	7	1	1	8	7	1	1	8	75.00
108	KIT, HIST	Remfg	2	20	3	1	23	20	3	1	23	20	3	1	23	150.00
110	KIT, MICROBIOLOGY	Remfg	1	40	5	1	45	40	5	1	45	40	5	1	45	50.00
114A	KIT, MICRODISSECTION	Remfg	2	40	5	1	45	40	5	1	45	40	5	1	45	75.00
118	LYPHILZR	Redesign	2	200	20	1	220	200	20	1	220	200	20	1	220	1400.00
121	MASS MEAS, MACRO	Minimal	1	20	10	1	30	20	10	1	30	20	10	1	30	760.00
122	MASS MEAS, MICRO	Redesign	3	2000	20	1	2020	2000	20	1	2020	2000	20	1	2020	980.00
126A	MICRSCP, DISECTNG	Minimal	1	10	5	1	15	10	5	1	15	10	5	1	15	900.00
128	MILLIPORE FLT APPRTS	Minimal	0			0	0	3	1	1	4	3	1	1	4	50.00
143D	PURGE SYS, CAT BURN	Remfg	2	100	20	1	120	100	20	1	120	100	20	1	120	2000.00
159	STAIN SYS, BACTERLGCL	Redesign	4			0	0	400	20	1	420	400	20	1	420	1500.00
179	TEMP BLOCK	Minimal	1	5	1	3	8	5	1	3	8	5	1	3	8	100.00
186	VOLUMTRC MEAS, LIQ	Redesign	2			0	0	50	5	1	55	50	5	1	55	
	TOTAL COST ESTIMATES			5152	233		5385	6245	319		6614	6670	484		7184	

each of the EIs was calculated first, followed by the EU cost distributions, and finally the laboratory cost distributions. A cost model was developed to do this, and the basis for that model was the NASA idealized cost distribution curves, Figure 8-5, taken from the cost planning guidelines section of the study contract RFP.

These curves indicate typical expenditure rates for the development of NASA hardware. Some of the EIs in the Life Sciences Laboratories will follow each of these cost rate curves; i.e., to develop some of the equipment will required spending funds at a high rate early in the development period, while the development of other equipment will require spending at a high rate late in the period. Development of individualized cost rate curves for each of the EIs was beyond the scope of the present task. Since we were working with a large number of EUs ($\approx$ 200), we assumed that the average cost rate curve would exhibit the statistical central tendency and be best represented by curve 3 shown in Figure 8-5. Curve 3 then was the basis for our cost models. Its equation is:

$$Y = 30s^4 - 60s^3 + 30s^2$$

where Y, funding rate, is the fraction of cost/time and s is fraction of time elapsed. The corresponding cumulative cost equation (the area under curve 3) is:

$$C = 6s^5 - 15s^4 + 10s^3$$

where C, cumulative cost, is the fraction of cost consumed.

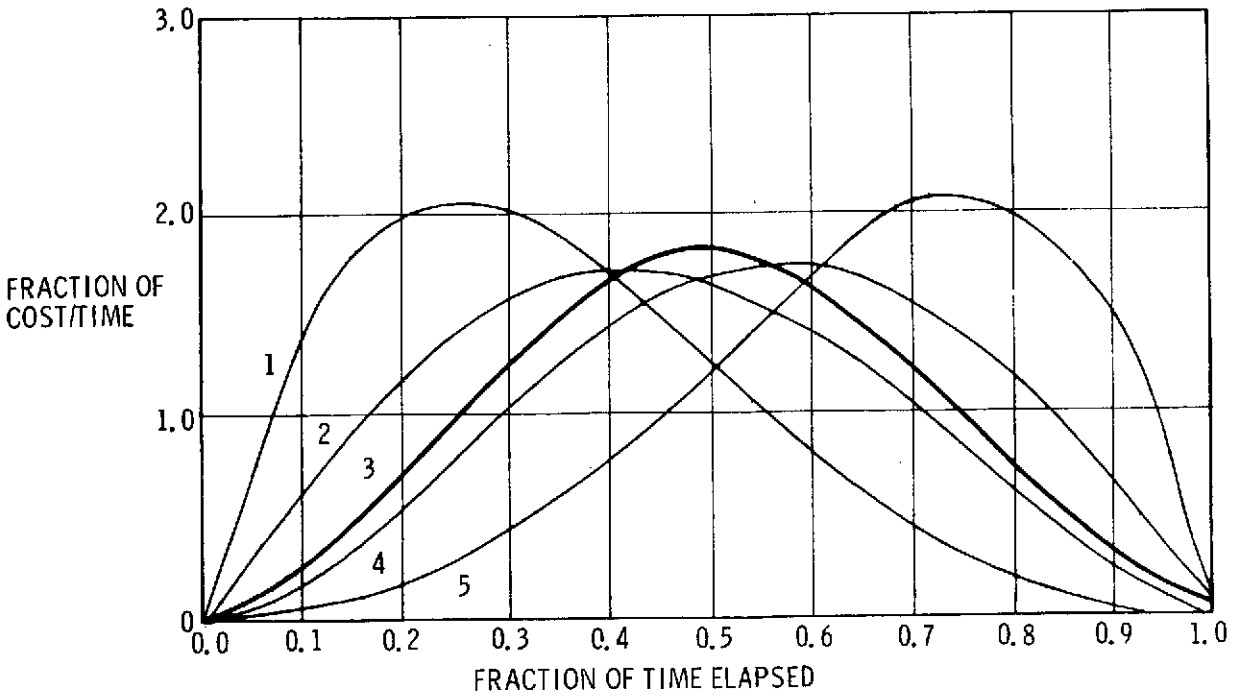


Figure 8-5. NASA Idealized Cost Distribution Curves
Cost Rate Curves

8.2.2.1 EI Cost Distributions. EI cost distributions were obtained by calculating a development cost distribution and a production (unit) cost distribution using these equations, the updated development and unit costs, the development time estimates for each equipment item, and the development-production phase assumptions shown in Table 8-2.

Table 8-2. EI Development-Production Phase Assumptions

EI Development Time Estimate (yr)	Spread of the Cost Distribution	
	Development Phase (yr)	Production Phase (yr)
1	0.00 to 0.75	0.50 to 1.00
2	0.00 to 1.50	1.25 to 2.00
3	0.00 to 2.25	2.00 to 3.00
4	0.00 to 3.00	2.75 to 4.00

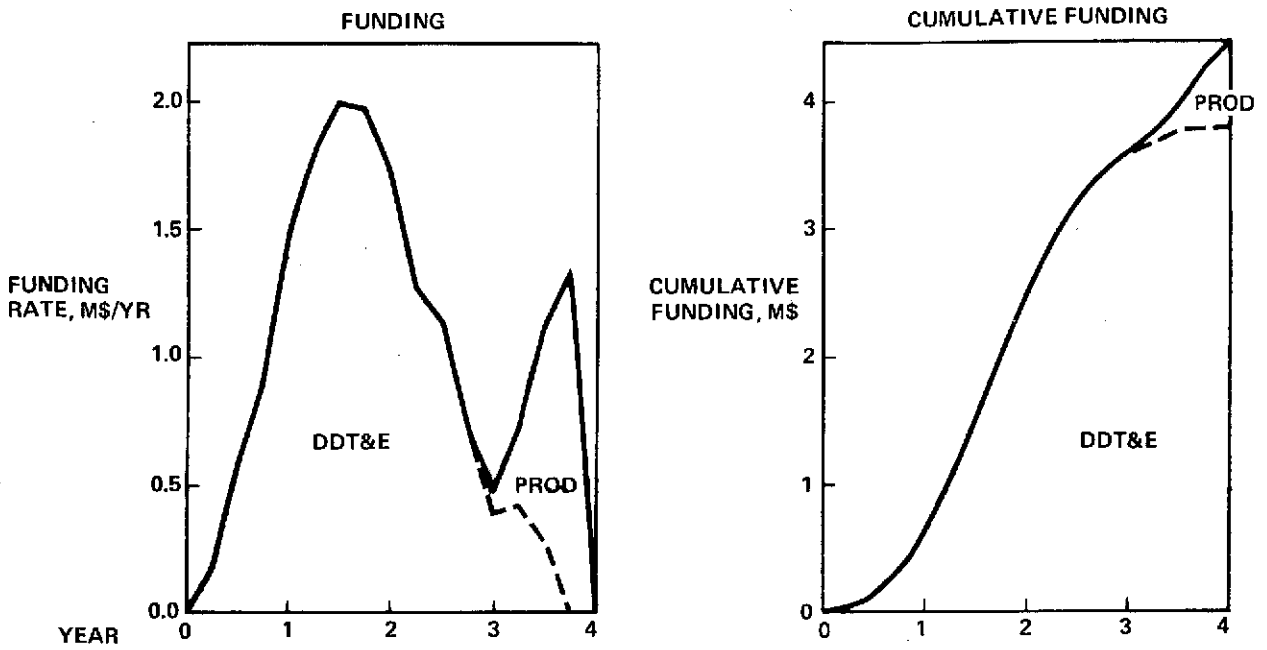
These development and production cost distributions were combined to obtain the cost distribution for each equipment item.

8.2.2.2 EU Cost Distributions. EU cost distributions were calculated by combining appropriate EI distributions. These were combined so that all EIs would be completed at the same time. This is consistent with the assumption that the 4-year EIs are the most complex and should be initiated first, followed by the 3-year EIs, etc.

The resulting cost distribution curves at the equipment unit level are of two types: a funding rate curve in millions of dollars per year and a cumulative funding curve in millions of dollars. Figure 8-6 is an example of these curves for Equipment Unit 1 — Visual Records and Microscopy Unit, Dedicated (30-Day) Laboratory. Each curve illustrates development (i.e., design, development, test and evaluation) and production data. Development, production and total annual costs are listed in tabular form under the funding rate curve, and similar cumulative costs are tabulated under the cumulative cost curve.

Funding rate, cumulative cost, and annual cost data for each EU in each payload are tabulated in Volume III, Appendix III.

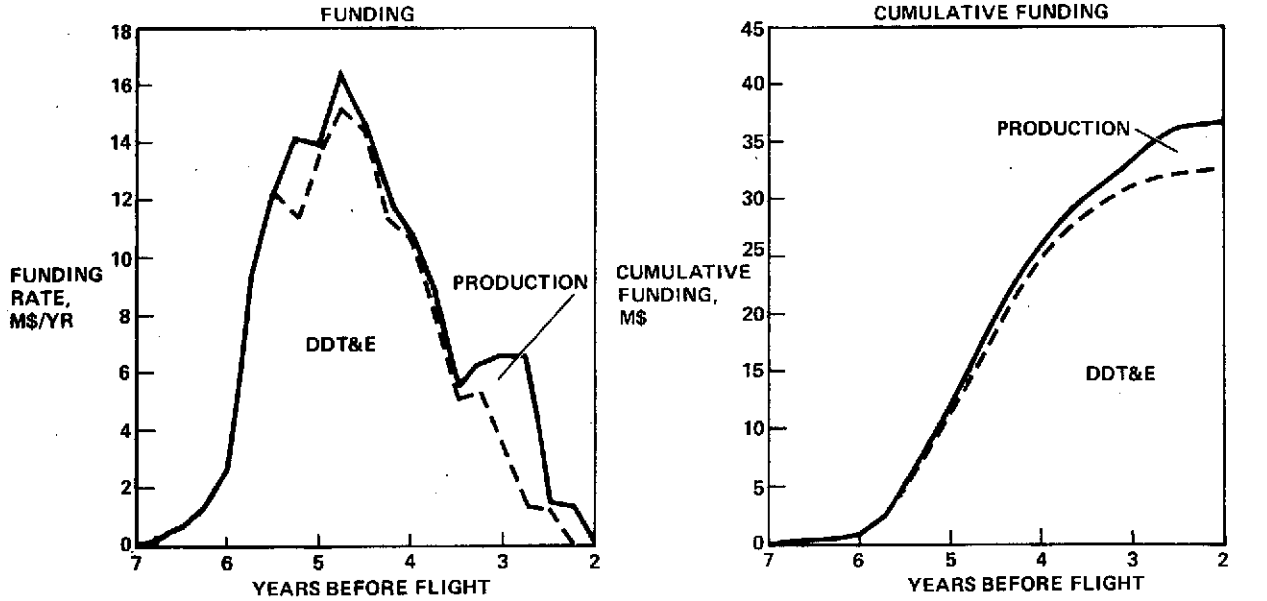
8.2.2.3 Laboratory Cost Distributions. Laboratory cost distributions were calculated by combining the EU distributions according to the EU development schedule discussed in Section 8.1. Figure 8-7 illustrates these distributions for the Dedicated (30-Day) Laboratory. The format is the same as the EU format. Annual funding requirements in millions of dollars are shown under the left-hand set of curves, and cumulative funding requirements in millions of dollars are tabulated under the right-hand set of curves.



DEV	0.63	1.86	1.09	0.22
PROD	0.00	0.00	0.01	0.63
TOTAL	0.63	1.86	1.10	0.85

0.63	2.49	3.57	3.79
0.00	0.00	0.01	0.64
0.63	2.49	3.58	4.43

Figure 8-6. Sample EU Cost Distribution Curves EI1 — Visual Records and Microscopy Unit Dedicated (30-Day) Laboratory



DEV	0.91	10.50	13.48	6.48	1.10
PROD	0.00	0.68	0.63	0.95	2.12
TOTAL	0.91	11.18	14.11	7.43	3.22

0.91	11.41	24.89	31.37	32.46
0.00	0.68	1.31	2.26	4.8
0.91	12.09	26.20	33.63	37.26

Figure 8-7. Sample Laboratory Cost Distribution Curves Dedicated (30-Day) Laboratory

Funding rate, cumulative cost, and annual cost data for each laboratory are tabulated in Volume III, Appendix III.

8.2.3 TOTAL LABORATORY COST ESTIMATES. The research equipment costs within each laboratory are only a part to the total cost. Additional costs were also determined to estimate the total laboratory funding requirements. These costs include the organism EC/LSS costs, which are specific to the Life Sciences Laboratories, and the following costs, which are determined using methodology from previous Convair Aerospace cost studies:

a. Laboratory Integration — Includes equipment interface hardware, integrated software, and integrated testing, and was estimated to be 50 percent of total equipment cost.

b. Laboratory Maintenance and Refurbishment — Estimated to be 50 percent of total equipment cost for a nominal 10 year program duration.

c. Equipment Spares — Estimated to be 200 percent of the equipment unit costs for a nominal 10-year program based on 50 percent of unit cost for initial spares and 15 percent of unit cost per year therafter.

The costs for the sortie module and baseline subsystems, launch operations, flight operations, ground support equipment, and ground-based mission support facilities were not estimated in this study.

The total funding required to develop each laboratory independently and use it for a nominal 10-year program is indicated in Table 8-3. Since the more probable case will be an evolutionary laboratory development, where the Shared 7-Day Laboratory is developed first and used early in the program, followed by the Dedicated 7-Day Laboratory, and finally the Dedicated 30-Day Laboratory, a program model was assumed to allow the estimation of an evolutionary laboratory development cost, also shown in Figure 8-7. The indicated mission duration was assumed for each of the laboratories as well as a savings of approximately 50 percent in the cost of integration and spares for the two dedicated laboratories because of prior development on the preceding laboratory.

Table 8-3. Cost Summary ($M)

COST ELEMENT	LABORATORIES		
	SHARED (7-DAY)	DEDICATED (7-DAY)	DEDICATED (30-DAY)
RESEARCH EQUIPMENT:			
DEVELOPMENT	21.8	29.1	32.5
PRODUCTION	2.1	4.2	4.8
ORGANISM ECS	4.8	6.3	6.3
LABORATORY INTEGRATION	14.4	19.8	21.8
LAB MAINTENANCE & REFURBISHMENT	14.4	19.8	21.8
EQUIPMENT SPARES	4.2	8.4	9.6
INDEPENDENT LABORATORY DEVELOPMENT	61.7	87.6	96.8
BASED ON MISSION DURATION (YEARS)	1	2	7
EVOLUTIONARY LABORATORY DEVELOPMENT:			
△COSTS	45.9	27.4	36.4
CUM COSTS	45.9	73.3	109.7

SECTION 9

EXPANSION OF COMPUTER PROGRAM CAPABILITIES

The current Life Sciences Payload Definition (LSPD) computer program is capable of defining the necessary research equipment for a variety of payloads. These payloads range from shared shuttle-sortie missions of seven days to permanent dedicated Life Sciences Laboratories attached to earth-orbiting space stations. While the current program has a notable degree of flexibility, its scope, flexibility, and usable output could be significantly expanded with some additional effort. The modified program would be a highly versatile tool in the planning of Life Sciences payloads, from the small carry-on variety to the largest laboratories.

Before the proposed modified program is discussed, a review of current program capabilities is appropriate. This will be followed by a critique of its usefulness based on the experience gained by Convair Aerospace in applying the program during the initial LSPD program and the integration effort just completed. Finally, the recommended changes to the program and its inventories will be discussed.

9.1 CURRENT CAPABILITIES

The current program and its inventories allow the user to select the functional capability that he desires for a given payload and the method that he desires to use to accomplish that function. As an output, he receives the following information:

a. A description of each selected function. This includes an estimate of the function's criticality (i.e., how important the function is to the accomplishment of the mission); the user FPE (functional program element; what discipline is required by that function — invertebrate research, biomedical research); the general classification of the function (e.g., experiment measurements and analysis, specimen maintenance); an indication of where the function should best be performed (e.g., on orbit, after return to ground); and a classification of the desired mode of the function as either automatic, semiatuomatic, or manual.

b. A description of each method selected to accomplish that function. This includes an estimate of how well this method achieves the desired accuracy of the function; an estimate of the crew time required to complete the function using that method; the primary and secondary crew skills required by that method; and a ranking of the degree of hazard of the selected method.

c. A listing of each equipment item necessary to accomplish the function and an estimate of the redundancy necessary for that item, the relative degree of interface between that item and the crew, the relative degree of logistics support required by that item, and the relative ease of maintenance of that item.

d. A detailed description and grouping of these equipment items by equipment unit (EU) — a categorization of the equipment items by the nature of their intended application. These descriptions include the total number of each item required for the payload and the number required by each using FPE; each item's weight, rate of power consumption, and volume; and the total weight, volume, development cost, unit cost, and rate of power consumption for each type of equipment item.

e. A summation of the weight, rate of power consumption, volume, unit cost, and development cost by EU.

f. A grand total for each variable in item (e) above for the entire payload. A footnote defines the indicated rate of power consumption identified above as being the rate required if all the equipment items were on all the time. A rule of thumb of ten percent of that number is given as an estimate of the actual rate of power consumption.

Payload definition using this program has considerable flexibility. A new payload can be selected simply by increasing or decreasing the functional requirements, and many of the parameters of interest are immediately available as output.

9.2 EXPERIENCE WITH THE CURRENT PROGRAM

The current program was developed and used during Phase I of the LSPD contract and has also been used to define Life Sciences payloads in the current study phase. Its flexibility has been proven, as six different payloads have been readily identified for selected functional capability levels in support of the LSPD objectives.

While the given output (weight, volume, development and unit costs) is highly useful to program planners, it is deficient in several important categories. A payload's impact on vehicle resources (e.g., electrical power production capacity, crew available time, data management capabilities) is only roughly estimated or not estimated at all. Therefore, time-consuming manual analysis is required to complement the computer output in these areas. This requirement could be eliminated with a modification to the program and its inventories so that an accurate value for average rate of power consumption, crew support requirements, and data management requirements are printed out in the output.

Other tasks currently being completed by manual means that have a potential for automation are the specification of the environmental requirements of a payload (acceptable loads, noise and vibration levels) and the estimation of payload parameters using commercially available equipment wherever possible (this option accepts the weight and volume penalties associated with commercial equipment to gain the advantage of lower cost).

Our experience with the current program has also revealed a constraint on its applicability. The current program was developed to define payloads varying in size from the shared shuttle payload (Mini-7 or Shared-7) to the ultimate space Life Sciences Laboratory, the space station supported Maxi-Max. The current phase of the LSPD study had a requirement to define a new type of payload, the sortie carry-on payload, that is much smaller than any envisioned when the existing computer program was developed. While the equipment in the computer equipment inventory is still applicable to these smaller payloads, the configuration of much of the equipment is not. For example, the freezer required for preservation of biological samples on the Sortie-Shared payload is a 7.0 ft^3 (50-pound freezer, which is much larger than that required for carry-on payloads (which are constrained to a total volume of 30 ft^3 and a total weight of 300 pounds). All that is necessary is a 1.5 ft^3 30-pound freezer. Another example is the amount of movie film required. The minimum unit available in the inventory (sized for Shared payload requirements) weighs 50 pounds, clearly much more film than required for the carry-ons. These two examples illustrate the types of changes required in the inventories. The former required the addition of a new equipment item to the inventory, a mini-freezer. The latter requires a reduction in the size of the basic film unit contained in the inventory to that which is acceptable for use on a carry-on payload. Then the number of the film units required by the other payloads would have to be increased to compensate for the film unit's smaller size. A series of these inventory modifications are required before the computer program can efficiently define mini-payloads such as the carry-on type.

Use of the program and its inventories has also revealed the necessity for a number of administrative-type corrections, which would improve the clarity of program output and the efficiency of its use. These include regrouping of the functions in the function inventory by specific categories, correction of overlapping functions, updating information, expanding skill categories, and correcting crew time estimate discrepancies.

9.3 PROPOSED MODIFICATIONS

To expand the capabilities of the present program, the following tasks are proposed:

a. Modify the electrical power requirements calculation. The present program prints out a number that is the total rate of power consumption if all the equipment were on at once, a highly inflated power required total. The 10 percent rule-of-thumb results in a better estimate, but it is still over or under the real value by as much as a factor of 10 (comparing rule-of-thumb power for each EU versus manually calculated average power).

   The output could be corrected by incorporating into the program the following information:

   1. An expanded version of the current operations model (a frequency table that documents the estimated frequency of occurrence of each function selected

for a given payload). An estimated frequency of occurrence would be added to the function inventory on the appropriate 7 card (number required card) for that function.

2. An estimate of the length of time that each equipment item is used for each function. These data would be added to each 4 card (equipment card) in the functions inventory.

The program could then read the estimated frequency of occurrence of each function, the time that an equipment item is being used (drawing power) on that function, and the power requirements of that equipment item (from the equipment inventory), and calculate an accurate average rate of power consumption over some preselected time base (e.g., 24 hours). The total average power for all of the EIs in the payload would give an accurate estimate of payload rate of power consumption.

b. Calculate payload manpower requirements by skill category and calculate equipment usage rates. The current functions inventory lists the crew time and skills required to accomplish each function. That information, the operations model discussed above, and an assumed crew duty cycle could be read by the computer, and an estimate of the number of men of each skill category that are required on a given payload could be calculated. Additional data in code form would be added after the crew times in the functions inventory to indicate which functions require more than one man simultaneously (e.g., a biomedical experimenter and his subject) to improve the accuracy of these results. The information developed for Tasks 1 and 2 could also be used by the computer to calculate crew usage rates for each equipment item, thus generating valuable data for workspace designers.

c. Identify the significant operational and environmental requirements of a given payload. Any unusual operational or environmental requirements of a selected function could be included in code form on the 3 card (function/method card) and recognized by the computer as it scans the selected functions. For example, if the housing function for a certain plant species requires unusually low acceleration levels, this constraint along with the others indicated for the functions in that payload could be printed out in the computer output as constraints required by that particular payload.

d. Calculate the payload data management requirements. The amount of data produced by an equipment item during a given function has a major impact on spacecraft resources. The information of interest in determining data management requirements of a payload would be factors such as the type of data produced (digital or analog), bits per second or bandwidth and number of channels, frequency and duration of data output, and recording requirements. Selected data production information could be placed on the 4 card, or an additonal card, for

each equipment item on each function. The computer could use that data along with the function frequency and duration from the operations model and the functions inventory to calculate data management requirements for a given payload.

e. Calculate payload parameters for commercial equipment payloads. Current equipment items in the equipment inventory are configured according to traditional aerospace requirements (i.e., flight equipment that is lightweight, compact), and the development and unit costs reflect that requirement. Therefore, the total weights, volumes , and costs do not reflect a stated desire by NASA of accepting in certain cases the weight and volume penalties associated with using off-the-shelf equipment to lower overall costs. These commercial costs are being manually estimated in the current phase of the LSPD study. Commercial parameters (weight, volume, and cost) could be included on the 3 and 4 cards of the equipment inventory and a second summation of payload parameters printed out to allow comparison between the traditional aerospace payload parameters and those obtained if off-the-shelf items are used wherever possible.

f. Update and restructure the functions inventory. The functions inventory would be updated to include the data required in the above calculations and new data coming from Skylab, IMBLMS, and other current programs. Administrative improvements would include grouping the functions by selected categories to ease the payload planners initial task, that of selecting the functional capability for a given payload, as well as assiting other users of the inventories. It would also include eliminating redundancies, eliminating information that is no longer used, and increasing the number and quality of explanatory notes to improve clarity.

g. Update and restructure the equipment inventory. The tasks necessary to update the equipment inventory are much the same as those necessary for the functions inventory. An additional task would be to include those small EIs required by the carry-on payloads.

SECTION 10

SUPPORTING RESEARCH AND TECHNOLOGY RECOMMENDATIONS

This section reviews in detail the six areas determined by this study to require significant SRT activity. Figure 10-1 summarizes the areas and the justification for their selection as SRT items.

Area	Justification
Organism Holding Units	Required by all research organisms except man. Required for PI acceptance tests and ground controls.
Bioexperiment Support-Transfer	Dictates requirements for spacecraft interface and ancillary equipment
Organism ECS	Required for all Life Sciences Laboratory concepts.
Laminar Flow Bench	Required for organism handling and sampling. Significant interface with analysis EUs. Provides isolation between organism and crew.
Video Data Control Unit	Design concepts influence research protocols. Requirements interface with holding units and ancillary equipment.
Internal Centrifuge Definition Study	Design driver in determining laboratory size. Dictates ground support facility requirements. Establishes and influences research protocols

Figure 10-1. Supporting Research and Technology

10.1 CAGE MODULES FOR ORGANISM HOLDING

10.1.1 PURPOSE. The purpose of the cage modules is to house various types of research organisms during both flight and ground operations. A cage module is a standard-sized cabinet into which various organism cages can be placed. This cabinet provides structural support for the organisms, a sealed enclosure which can be isolated from the cabin atmosphere, and electronic equipment to control the cage module environmental parameters and monitor the organisms. The cage module is intended to interface with separate subsystems that will provide ventilation air, electrical power, thermal control fluids, and data management functions.

10.1.2 GENERAL REQUIREMENTS. The cage module should be capable of supporting most of the organisms shown in Table 10-1. Sizing of the cage module should be based partly on statistical requirements for biological research. Typically, a biological experiment group will contain 32 organisms. Any submiltiple of 32 is considered appropriate.

Table 10-1. Candidate Space Research Organisms

Small Vertebrates	Plants	Invertebrates
Mice	Marigold	Flies
Rats	Arabidopsis	Gnats
Frogs	Garden Pea	Cockroach
Goldfish	Bean	Spiders
Turtles	Corn Seedlings	Planaria
Chickens	Wheat	Flour Beetle
Quail	Pepper	
Marmots	Various Seeds & Seedlings	
Hamsters	Spider Wort (Tradescantia)	
Squirrels	Green Alga	
Salamanders		
Rabbits		
	Cells and Tissues	
	Frog Eggs	
	Carrot Tissue	
	Parsnip Tissue	
	Chick Embryo (Eggs and Tissue Culture)	
	Neurospora	
	Various Animal Tissue Culture	
	Various Microorganism Cultures	
	Various Plant Tissue Culture	
	Viral Culture (Tissue Culture, Armyworms, Bacteria)	

Dimensions must also be compatible with the sortie module hatch, which is 152 cm (60 in.) in diameter. The cage module should also be small enough for manual manipulation in principal investigators' laboratories as well as in flight operations. Initial designs at General Dynamics Convair Aerospace have been based on a size suitable for holding eight rats.

In order to preserve the organisms during a decompression, the walls of the cage module should be capable of withstanding a burst pressure differential of 1 atm. The cage module must be hermetically sealed and thermally insulated to minimize heat transfer to and from the environment when operating with internal temperatures above or below ambient temperatures.

The caging systems for representative organisms should be developed along with the cage modules to ensure functional compatibility. The most complicated cages are those for the vertebrates. These require provisions for feeding, watering, waste collection, lighting, ventilation, and visual observations. Different sized cages for the various organisms should be compatible with the single-sized cage module allowing for minor

modifications in ventilation manifolds, support shelves, and attachment mechanisms. Vertebrate feeding can be accomplished by (1) pellets supplied from a belt or bin, (2) paste extruded from a feeding device, or (3) liquid dispensed from a valve device. Waste collection includes handling of feces, urine, and other minor bodily products such as hair. In zero-g as well as 1-g, the usual solution to this problem is to use a specially designed filter integral with each vertebrate cage. Ventilation ducting should be configured so that each cage within the cage module is supplied fresh air rather than effluent air from an upstream cage. Vertebrate cage lighting is required for several purposes: (1) as an organism stimulus, (2) for photography or video coverage, (3) for visual observations by the crew, and (4) for organism manipulation.

The cage module should also be adaptable to the housing of plants. In this case, complicated cages as for the vertebrates are not required. Instead, root-ball containers will be required with provisions for zero-g holddown, watering, and support of plants during various flight dynamic loading. Cage module lighting is a major consideration, with illumination levels on the order of 10,000 lumens/m^2 ($\sim$1000 ft-candles) required. Cage module ventilation must be low to prevent plant motion resulting from ventilation air flows.

As in the case of plants, cages for invertebrates and enclosures for cells and tissues are not expected to require extensive development effort. However, the cage module should be compatible with support of these organisms This will require provisions for cage module heating and accurate temperature control. Minor ventilation may be required for some experiments.

In addition to careful attention to internal integration with the cages and organisms, the cage module must be designed to interface with the external supporting subsystems. The major subsystems are the environmental control subsystem (ECS) and the data management subsystem (DMS). The cage module ducting must be sized to accommodate the required ventilation flow rates without excessive pressure drop losses. Filters used for fecal and urine containment should also be designed for minimum pressure drop and may incorporate activated charcoal for air purification. Air sterilization devices such as millipore filters may also be more easily incorporated in the cage module than in the external ECS air ventilation loop. In the case of the DMS integration, the electronic couplers contained in the cage module must be compatible with the DMS data acquisition and control devices. The cage modules should contain provisions for multiple couplers to take information from the biosensors and other cage module instrumentation and condition this information for transmission to the DMS.

Another requirement of the cage module is that it must be connectable to a laminar flow bench for crew manipulation of the organisms. The laminar flow bench is essentially a glove box that minimizes the cross-contamination of cabin and cage module air. It is the subject of a separate SRT as described in Section 10.4.

10.1.3 TECHNICAL DESCRIPTION. A preliminary concept of a cage module is depicted in Figure 10-2. It shows the cage module as it would look while housing eight rat cages. For smaller or larger vertebrates, the rat cages would be removed, and larger or smaller cages would be inserted. For plants, invertebrates, and cells/tissues, the cages would be removed and other appropriate holding devices would be used. The figure shows the eight rat cages and a preliminary concept of an integral feeding device and urine and feces collection tray under each cage. The concept also includes a TV camera on a positioning mechanism for the purpose of monitoring any one of the organisms. Protection of the camera optical system from extraneous debris would be provided. Electronic plug-in devices are contained in an upper shelf of the cage module. These are used for various controls and to condition biosensor signals for transmission to the data management subsystem.

Preliminary estimates of the properties of the cage modules and rat cages are given below.

Vertebrate Cage Module

Weight = 27 kg (60 lb), including cages, TV camera and drive mechanism
Volume = 0.24 m^3 (8.6 ft^3)
Power = 10 watts (electronics)

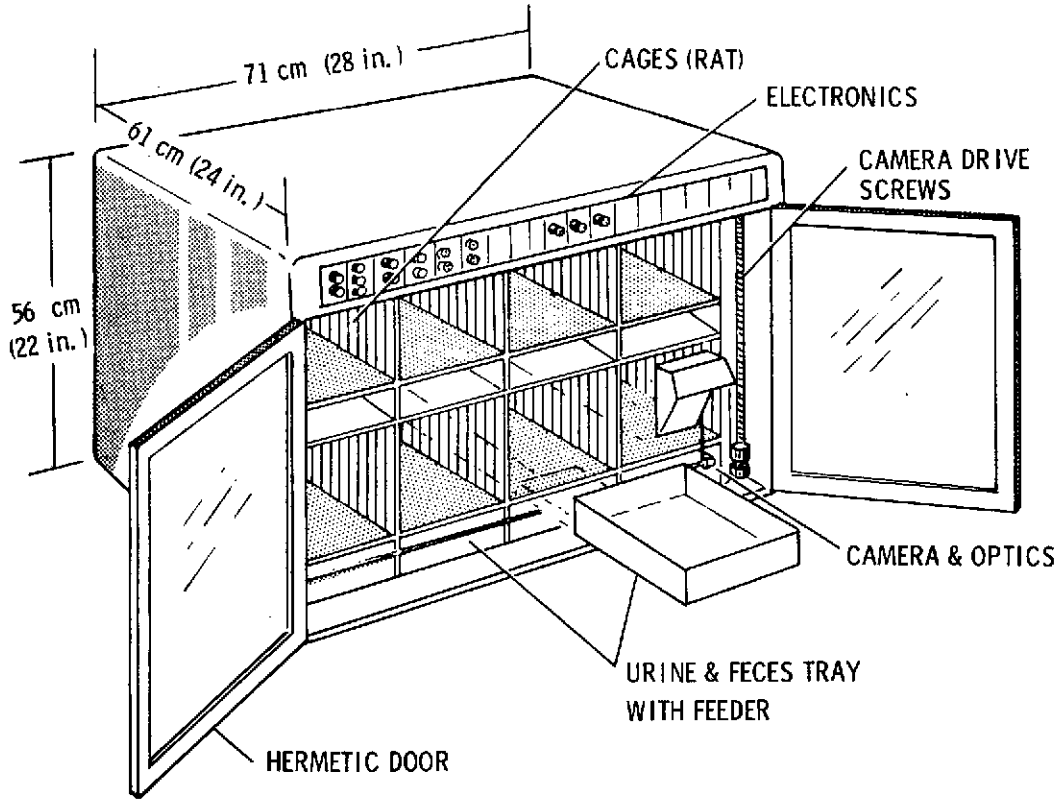


Figure 10-2. Cage Module

Rat Cage (Each)

Weight = 2.3 kg (5.1 lb)
Volume = 7.1 dm^3 (0.25 ft^3)
Power = 9 watts (lights)

Plant Cage Module (Modified for Plant Holding)

Weight = 27 kg (60 lb)
Volume = 0.24 m^3 (8.6 ft^3)
Power = 140 watts (primarily lights)

Invertebrate Cage Module

Weight = 36 kg (80 lb)
Volume = 0.24 m^3
Power = 50 watts (primarily heater)

Cells/Tissues Cage Module

Weight = 32 kg (70 lb)
Volume = 0.24 m^3
Power = 50 watts (primarily heater)

10.1.4 WORK STATEMENT. The development of a flight-qualified cage module was basically divided into two phases. First is the development and evaluation of a flight prototype, and the second is the construction and testing of the flight hardware, as shown in Figure 10-3.

The first step in the development of the prototype includes a preliminary design study, which would be closely coordinated with NASA. This would include the generation of design requirements and guidelines. Mockups would be fabricated to investigate hardware design aspects and to investigate man-machine integration factors. Following these preliminary activities, the hardware prototype design would be finalized and it would be fabricated and tested to ensure that it meets performance specifications. Following this hardware performance testing, the design would be subjected to testing and evaluation by several principal investigators to determine suitability from a biological research standpoint. It would also be tested at the NASA/MSFC concept verification test (CVT) facility to investigate spacecraft integration problems.

The second phase of the cage module development is the construction of a flight unit. The steps in this phase are similar to those in the development of the prototype. However, they would be much more involved to comply with the flight equipment specifications. Even though these specifications have been relaxes recently to reduce costs, they are still quite extensive and include specifications on materials, criticality, quality

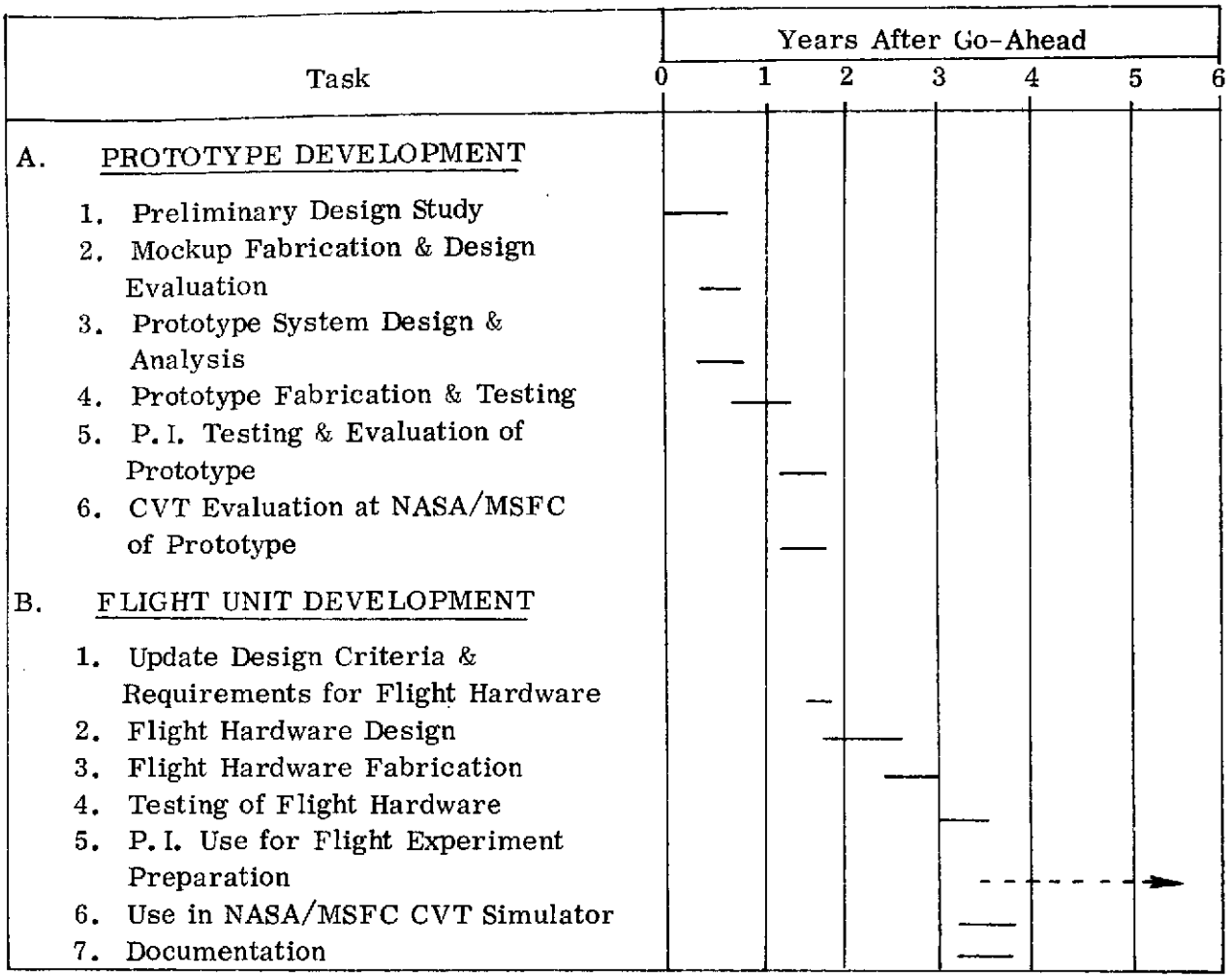


Figure 10-3. Cage Module Development Schedule

assurance, qualification testing, training, fluids, cleanliness, reliability, program management and documentation, Reference 8.

The first task in construction of a flight cage module, shown in Figure 10-3, is updating the design requirements as a result of the evaluation tests on the prototypes. Following this, the flight hardware would be designed, fabricated, and performance tested. This hardware would then be made available to principal investigator for use in setting up the flight experiments. These flight units would also be used by NASA in spacecraft simulator testing.

10.1.5 COST. The cost of completely developing the flight cage modules for the various organisms, including internal caging and typical electronic equipment for organism monitoring, was estimated to be $5.5 million. This number does not include the costs associated with extended use by the P. I. in preparation for flight experiments (dashed portion of the task line shown in Figure 10-3).

10.2 BIOEXPERIMENT SUPPORT AND TRANSFER UNIT (BEST)

10.2.1 PURPOSE. The purpose of the BEST is to provide the subsystems necessary to support the common cage module (Section 10.1) in a broad range of small animal, plant, and cells and tissues experiments. The unit is basically a transportable rack (Figure 10-4), containing a power source environmental control, contamination control, waste management, water management, and data management subsystem configured to hold and interface with the common cage modules.

10.2.2 GENERAL REQUIREMENTS. The BEST must provide the following:

a. A power supply and distribution subsystem to distribute power to the various operating components under normal operating conditions and to supply and distribute power while the BEST is being transported from one site to another.

b. An environmental control subsystem that allows the operator to maintain the desired, and usually different, environmental conditions for each common cage module. Temperature, humidity, and air flow must be individually controlled.

c. A contamination control subsystem to minimize cross-contamination between the experimenter and his experiments and between individual experiments. It must allow free access to the experiments for specimen and equipment manipulation and maintenance while providing the protective shield.

d. A waste management subsystem to handle the waste products generated by the small animal experiments.

e. A water management subsystem to supply water to the experiments as required.

f. A data management subsystem to sense, display and record the parameters of interest. This would include variables such as air and specimen temperatures, light levels, respiration rates, ECG, specimen activity levels, relative humidity, and soil moisture.

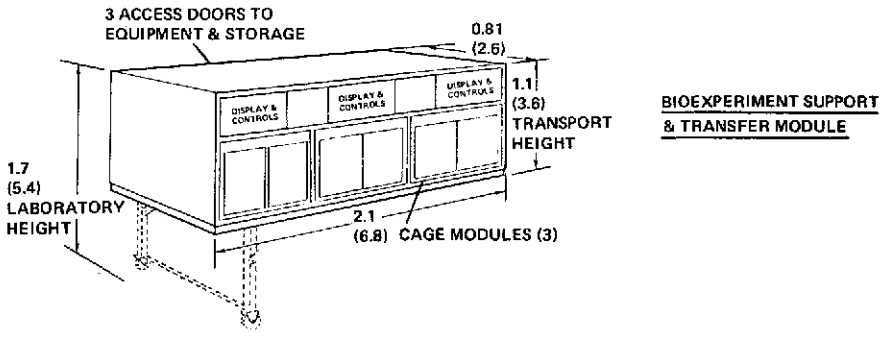


Figure 10-4. The Biological Experiments Support and Transfer (BEST) Unit

10.2.3 TECHNICAL DESCRIPTION. A prototype of the BEST has been built, preliminary engineering tests have been completed, and an initial evaluation by selected principal investigators was conducted at NASA/ARC in January 1973. Figure 10-5 illustrates this prototype, designed to support three common cage modules. The eight rat cages for small animal experiments can be seen through the transparent glove box in the left common cage module. The center module, with its doors closed, is equipped to support plant research, while the common cage module on the right supports research with cells and tissues.

The glove box provides an air-tight shield between the experimenter and his experiments. The experimenter can insert his hands and arms in the gloves and open or close the cage module doors and maintain experimental equipment without direct skin contact with the contents of the cage module. A pass through port in the bottom of the glove box, used in conjunction with a sterilization technique, enables specimens and parts to be placed into or removed from the cages without cross contamination. The cylindrical device in the center of the forward face of each glove box is a membrane-divided air chamber connecting suction tubes on the inside and outside that allow the experimenter to use oral suction or blowing as required for specimen manipulation (e.g., insect counting) and fluid sampling.

The upper portion of the BEST contains the data management and display/control subsystem. The controls allow the experimenter to simultaneously maintain different environmental conditions in each of the three common cage modules. The experimenter can also select the data that he wishes to display and/or record. The BEST circuitry is designed to handle five data groups consisting of eight measurements per data group, or a total of forty measurements (only part of this potential data acquisition capability is provided in the prototype). The following measurements can be made with the prototype:

a. Temperature (body and air).
b. Light intensity.
c. Respiration rate.
d. ECG.
e. Activity.
f. Relative humidity.
g. Resistance (soil moisture).

These measurements can be displayed on the digital readout, oscilloscope, and two-channel recorder provided in the BEST. The data can be stored on the two-channel recorder or on 1/2-inch magnetic tape. Design provisions in the circuitry enable conventional laboratory recording devices to be connected to terminals on the data acquisition circuit if desired.

During transport of the BEST, between the PI's laboratory and the launch site, for example, the BEST can be lowered to the lowest position on the transport base as shown in Figure 10-6. The suspension system for adjusting this height is an integral part of the transport base. Access to the subsystems is provided through the rear doors as illustrated in Figure 10-6.

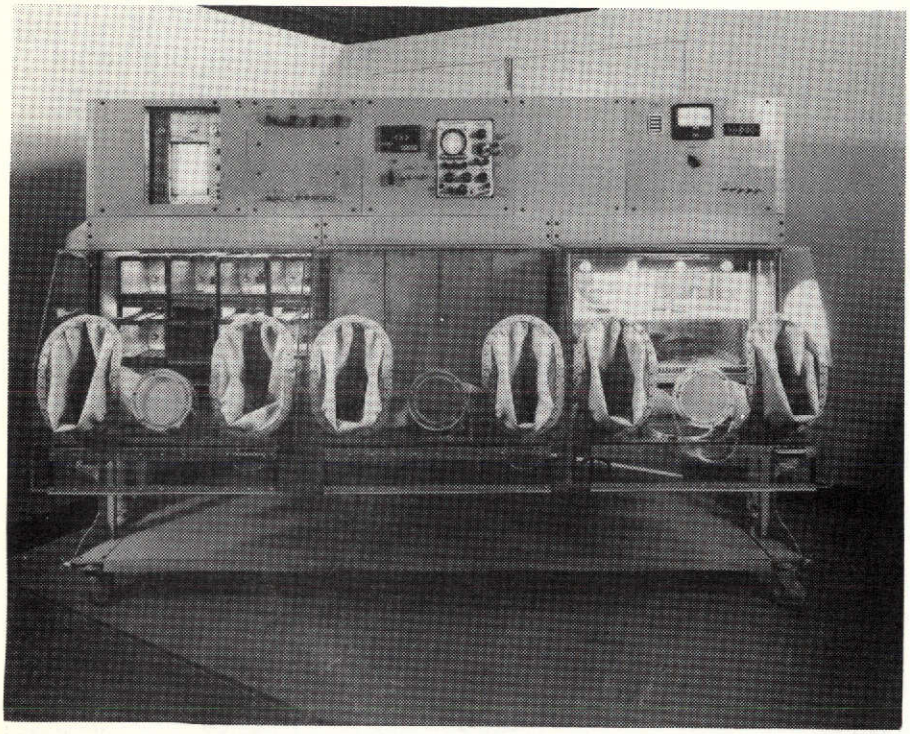


Figure 10-5. The BEST Prototype (Three Common Cage Module Version)

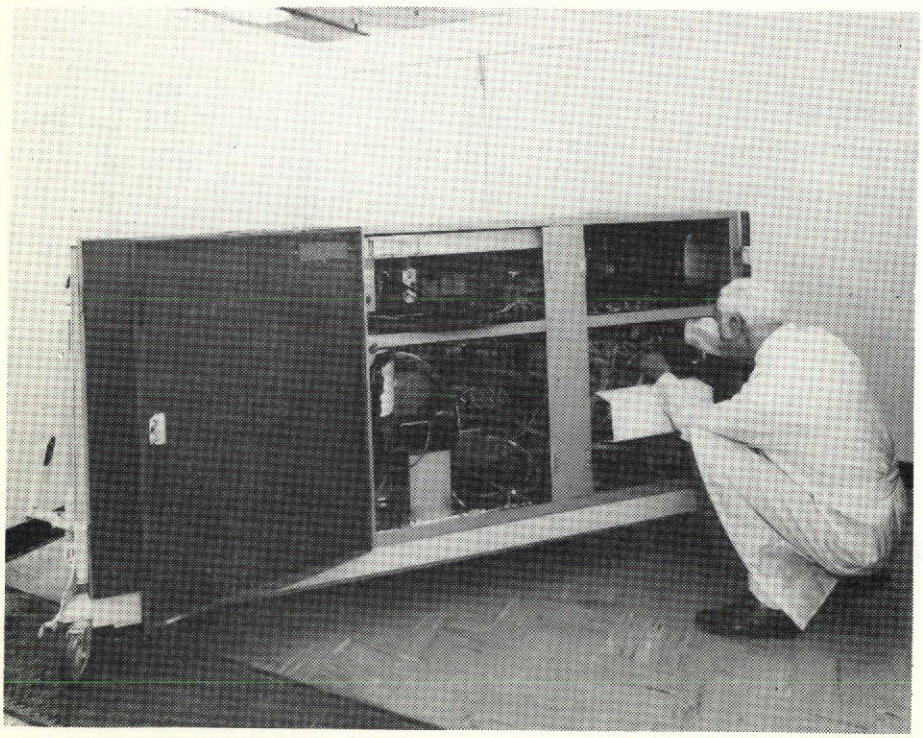


Figure 10-6. The BEST Prototype (Configured for Transport) Illustrating Rear Access Capability to Its Components

10.2.4 WORK STATEMENT. The development schedule of the Bioexperient Support and Transfer Unit (BEST) is shown in Figure 10-7. The program includes four major activities. This work statement will cover only Task A, the development of the second-generation BEST prototype.

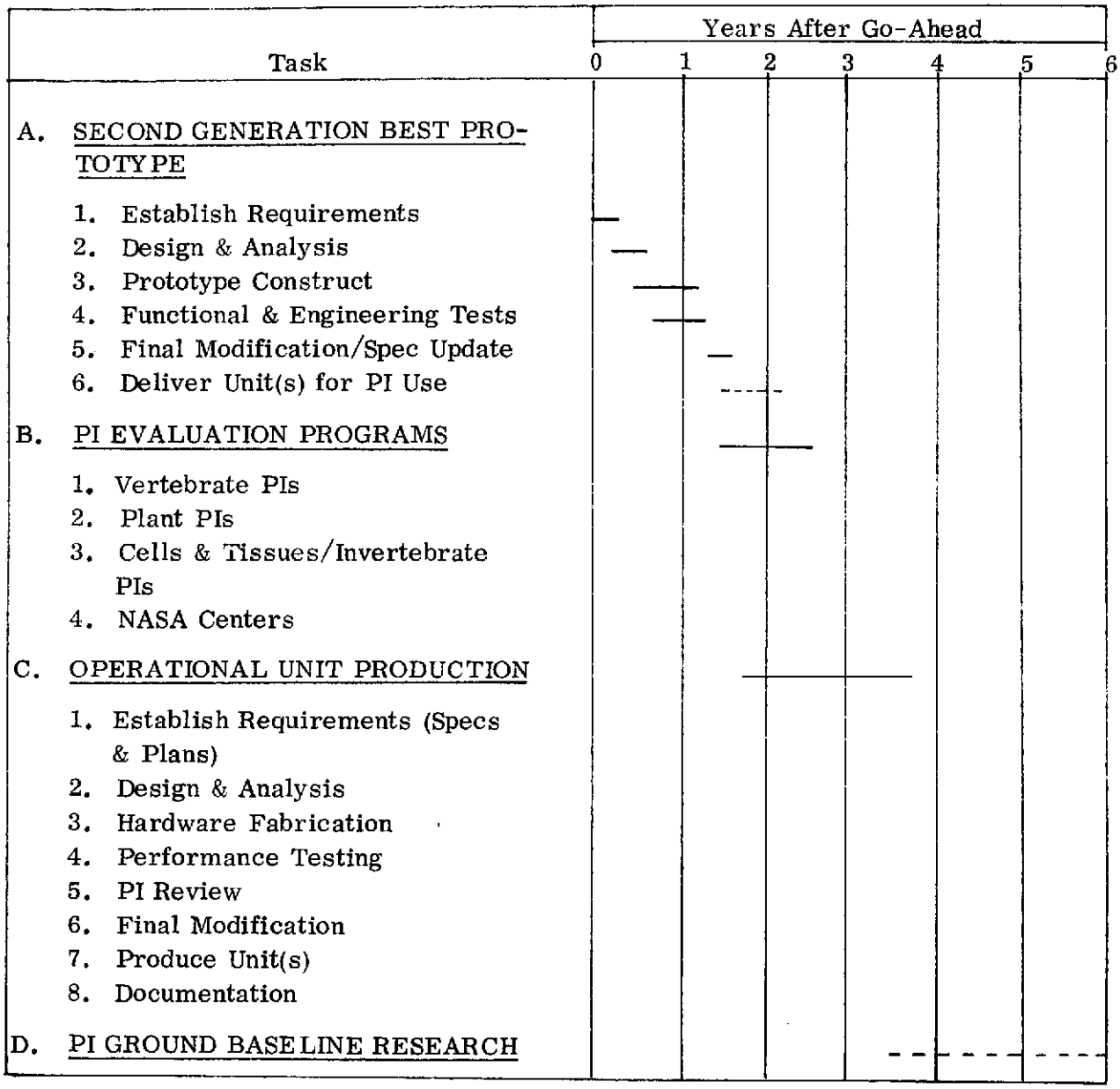


Figure 10-7. BEST Unit Development Schedule

The initial task involving the development of the BEST is aimed at a second-generation unit that incorporates the changes as suggested by the PI testing at NASA/ARC during January 1973. The PI requirements would be used to drive the analysis and design activity. This activity would involve the six areas outlined in the general requirements, Section 10.2.2.

The resulting design would be used to construct a second-generation prototype. Engineering tests would be performed to determine the ability of the unit to meet the design requirements. Final unit modification and specification update would be performed after the completion of the testing.

During the prototype development activity, plans would be made to have several PIs use the BEST units for in-house evaluations. The number of units and FPE configuration would be established at that time. These units would be developed under separate contract and devliered to the PIs for testing and evaluation.

10.2.5 COSTS. The cost estimate for one BEST unit, as described in Task A of the program schedule, is $150,000. Additional units to support PI evaluation programs during Task B are estimated to cost between $25,000 and $40,000, depending upon the desired configuration.

10.3 ORGANISM ECS

10.3.1 PURPOSE. Environmental control subsystems (ECS)* are needed to support the biological organisms to be used in space flight research. These subsystems should be developed in close conjunction with the development of the cage modules, which are used for housing most of the biological organisms; see Section 10.1.

10.3.2 GENERAL REQUIREMENTS. The organism ECS discussed here is intended for operation in the sortie modules, which have mission durations of 7 to 30 days. However, the ECS equipment should be designed to allow for the possibility of modification and use in future longer duration missions.

The organisms to be supported include small vertebrates, large vertebrates (monkeys), plants, invertebrates, and cells/tissues (see Table 10-1 for a list of typical organisms). The large vertebrates (monkeys) will be housed in separate holding units, and the rest of the organisms are to be housed in cage module holding units. These are hermetically sealed rectangular cabinets approximately 56 × 61 × 71 cm. The vertebrate organisms require ECS equipment with several orders of magnitude greater capability than that required by the plants, invertebrates, and cells/tissues.

The current guideline being used in the Life Sciences payload definition study is that the mixing of sortie module cabin air and air within the holding units be minimized. Therefore, ECS equipment separate from that required for the crew is required for the holding units. Furthermore, some degree of atmospheric isolation is required for different groupd of organisms, thus leading to the possibility of several ECS loops for the various holding units.

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*The term organism ECS rather than organism EC/LSS has been used throughout this report since the subject subsystem is primarily devoted to environmental control functions rather than life support functions.

Another general requirement of the ECS is that it provide similar atmospheric conditions for the organisms in the spacecraft to those on the ground. The ground systems are used over much longer periods of time (years) and therefore are not expected to use closed ECS loops with LiOH and stored oxygen. Instead, the ground systems will use ambient air, which will be conditioned to provide the desired temperature and humidity levels.

10.3.3 TECHNICAL DESCRIPTION. Preliminary ECS design analysis indicates that a single common ECS loop could be designed to satisfy the requirements of two cage modules containing small vertebrates (e.g., eight rats in each) or one primate cylinder containing a 9.1 kg monkey. A second basic ECS of much lower capacity can be used to support several cage modules containing invertebrates, plants and cells/tissues. Preliminary flow schematics of these two ECS loops are shown in Figures 10-8 and 10-9, and a more comprehensive discussion of them is contained in Section 3.1. These concepts use cooler-condensers for sensible cooling as well as dehumidification. This concept requires further study of off-design conditions and spacecraft integration factors before deciding upon a final technique for temperature and humidity control. Other possibilities include (1) the use of separate heat exchangers for temperature and humidity control, and (2) the use of silica gel for dehumidification. Other possibilities include (1) the use of separate heat exchangers for temperature and humidity control, and (2) the use of silica gel for dehumidification.

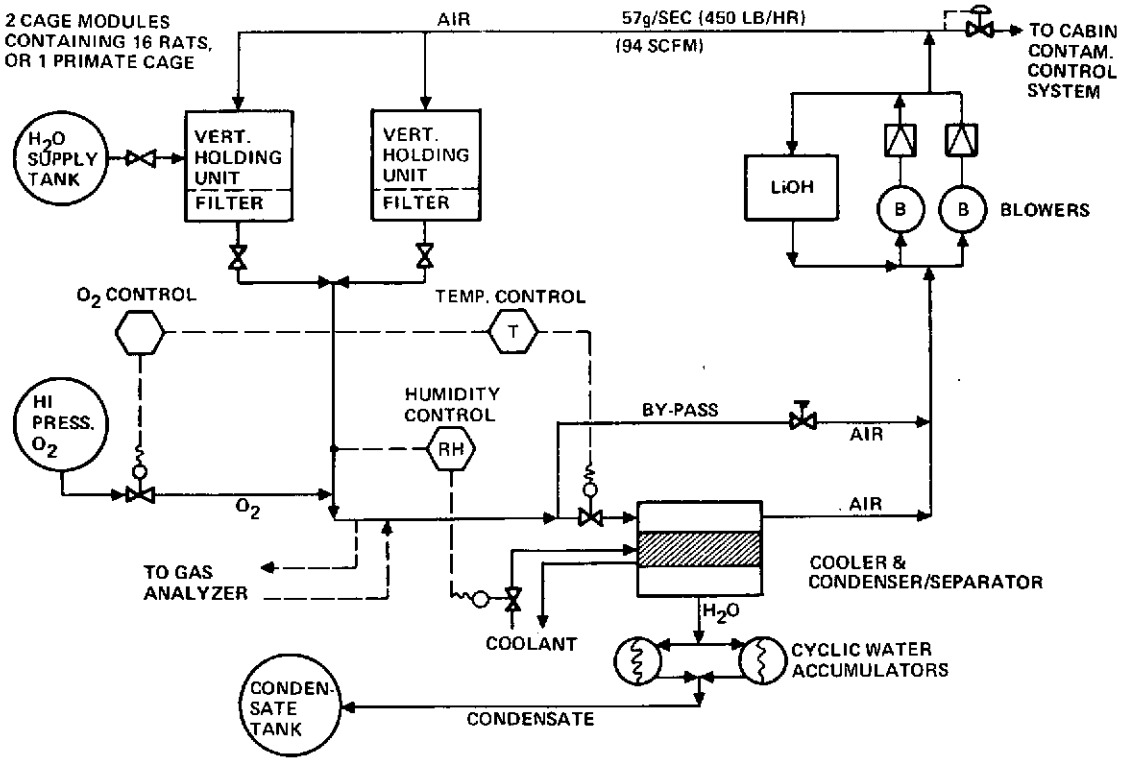

Figure 10-8. ECS Loop Concept for Vertebrate Holding Units

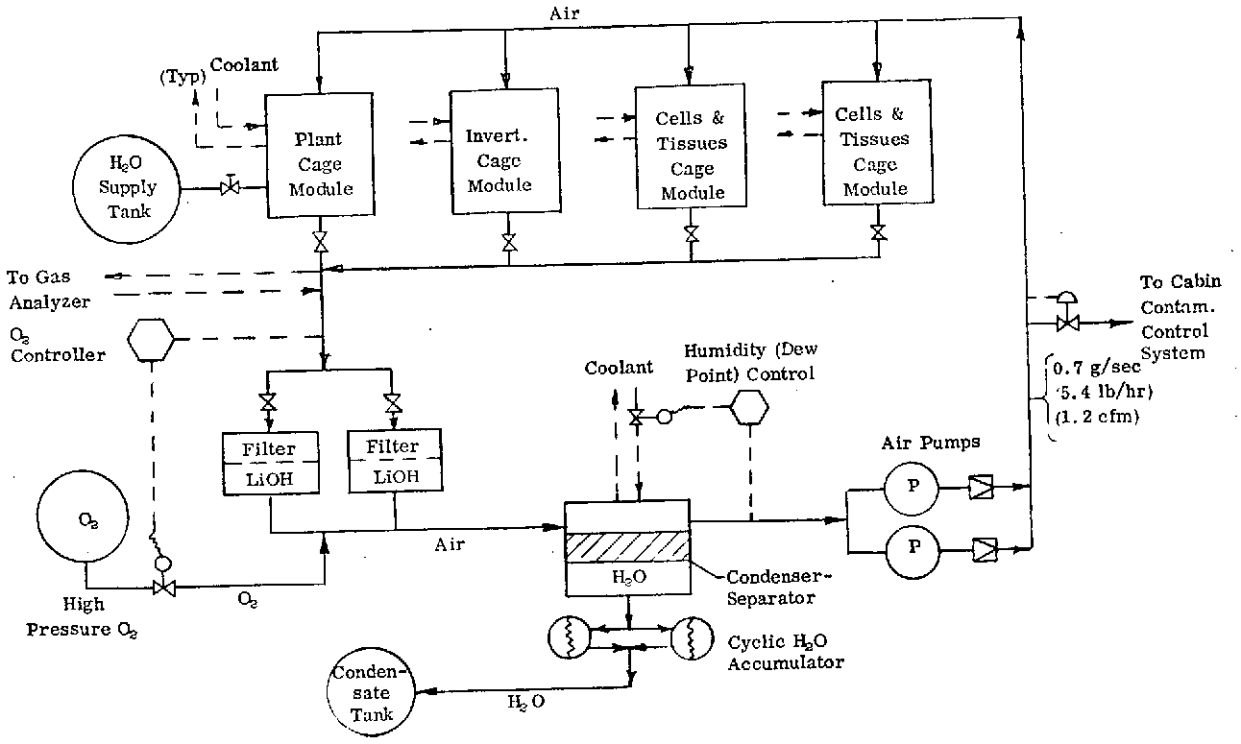

Figure 10-9. ECS Loop for Plants, Invertebrates, and Cells/Tissues

The concepts shown in the figures were also based on the requirement that the organism ECS air loops be isolated from the cabin air. This was done to prevent contamination of the cabin air by the air from the organism cage modules. The loop shown in the figure would operate at a pressure slightly lower than the ambient cabin pressure. Thus, any leakage would be into the organism loop, which would be pumped back to the cabin through the catalytic oxidizer aboard the sortie module.

10.3.4 WORK STATEMENT. The development of flight qualified organism ECSs has been divided into two phases. The first is the development of prototype systems and second the production of flight hardware, see Figure 10-10.

During the prototype development phase, the first task is to firmly establish requirements and design criteria in conjunction with NASA and the scientific community. The next task, of ECS design and analysis, will include a review of existing flight ECS hardware that could possibly be used in the organism ECS. This would include such items as heat exchangers, blowers, LiOH canisters, oxygen bottles, and water tanks. The use of such hardware would greatly reduce costs during the subsequent flight hardware production phase.

Task A-3 is the construction and testing of at least one breadboard ECS system to inexpensively check out such ECS characteristics as humidity and temperature control. These tests would be performed with simulated organism holding units connected to the breadboard ECS. Following breadboard testing and evaluation, the prototype systems

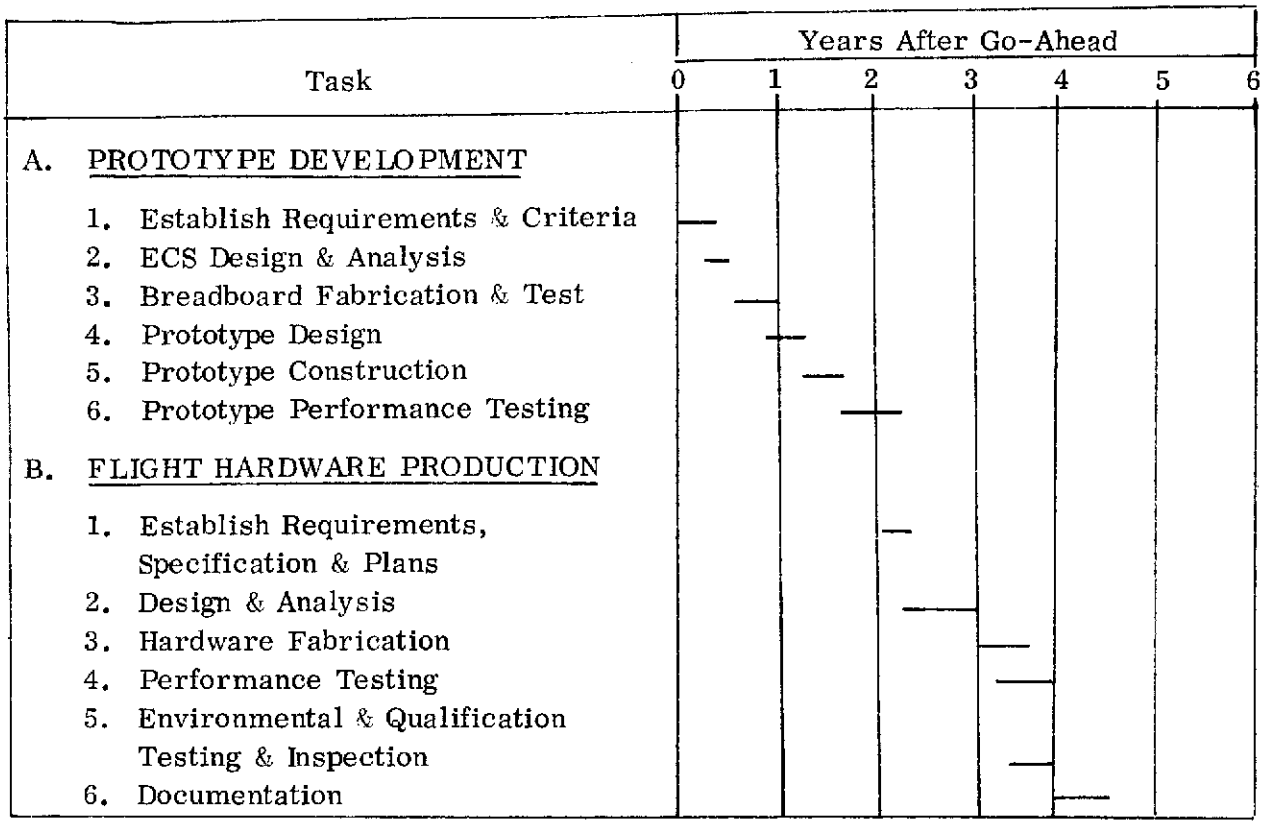

Figure 10-10. Organism ECS Development Schedule

would be designed, fabricated, and tested. The prototypes would be tested with sample organisms in enclosures simulating actual holding units. Tests would be run on the control characteristics of the ECS in the areas of temperature, humidity, O_2, CO_2, and trace contaminants, pressures, and water flows.

The second phase of the ECS development is the production of flight hardware. Detailed specifications and plans would be prepared, followed by analysis, design and fabrication of the hardware. The hardware would be subjected to various performance and qualification tests as fabrication and assembly progressed.

10.3.5 COST. The cost of complete development of the flight-qualified ECSs was estimated at $5 million. Unit costs were estimated at approximately $100,000 for a typical flight ECS loop. These costs do not include vehicle integration costs or spares costs.

10.4 LAMINAR FLOW BENCH (LFB)

10.4.1 PURPOSE. The LFB will provide isolation between the experimenter and the test organisms. This bench is basically a glove box with a directed air flow for control of potential particulate and gaseous contaminants. It will be used by the experimenter for a variety of procedures that require his interaction with the test organisms and specimens.

10.4.2 GENERAL REQUIREMENTS. The LFB must provide the following:

a. A laminar air flow system to maintain clear window vision and atmospheric isolation between the test subject and experimenter while keeping debris such as urine, feces, water, and hair away from the subject.

b. A portable workbench that can be appropriately outfitted for the desired task, and taken to the subject organism located at various sites within the laboratory.

c. An instrumentation complex (video display, CRT display) to allow setup and checkout of the experiment instrumentation (camera adjustments, bioelectronic calibration and adjustment, feed and water dispenser checkout).

d. A means of transporting samples from the organism holding units to the preservation and preparation equipment while maintaining isolation.

Glove box operations are also required for toxic chemical management and radiobiological research. Toxic chemical management will be accomplished in the LFB by interfacing with a cage module type equipment rack contining the chemicals.

Radiochemistires will be performed in the LFB by using a liner fabricated from shielding fabric and a shielding glass. In this case, the radiochemicals are contained in a portable device that can be moved throughout the laboratory as needed.

Other desirable features of the LFB include a data management interface, holddown devices for tools and small equipment, adjustable lighting, an air lock for specimen transfer, and a removable liner that can be autoclaved.

10.4.3 TECHNICAL DESCRIPTIONS. Preliminary conceptual designs have been made of an LFB. Figure 10-11 is a sketch indicating the basic configuration. The flight version is estimated to weigh 200 pounds and require 100 watts of electrical power. A soft mockup of an early version of the LFB is shown in Figure 10-12.

10.4.4 WORK STATEMENT. The initial task effort will involve a review of this SRT with the appropriate PIs to update the requirements for the LFB. An analysis will be performed and include at least the follwoing: (1) sealing requirements between the holding unit and the LFB, (2) the development of a proper air flow system, (3) the glove configuration, (4) the mobility requirements, either powered or man manipulated, (5) the data/display requirements, (6) the liner requirements for radioactive work, and (7) the definition of the liner requirements to provide for proper sterilization.

A design of a breadboard LFB system will be accomplished. The breadboard will be fabricated and tested. This testing will be used to evolve the appropriate man-machine design criteria, and to evaluate the compatiblity of the design with the (PIs) requirements.

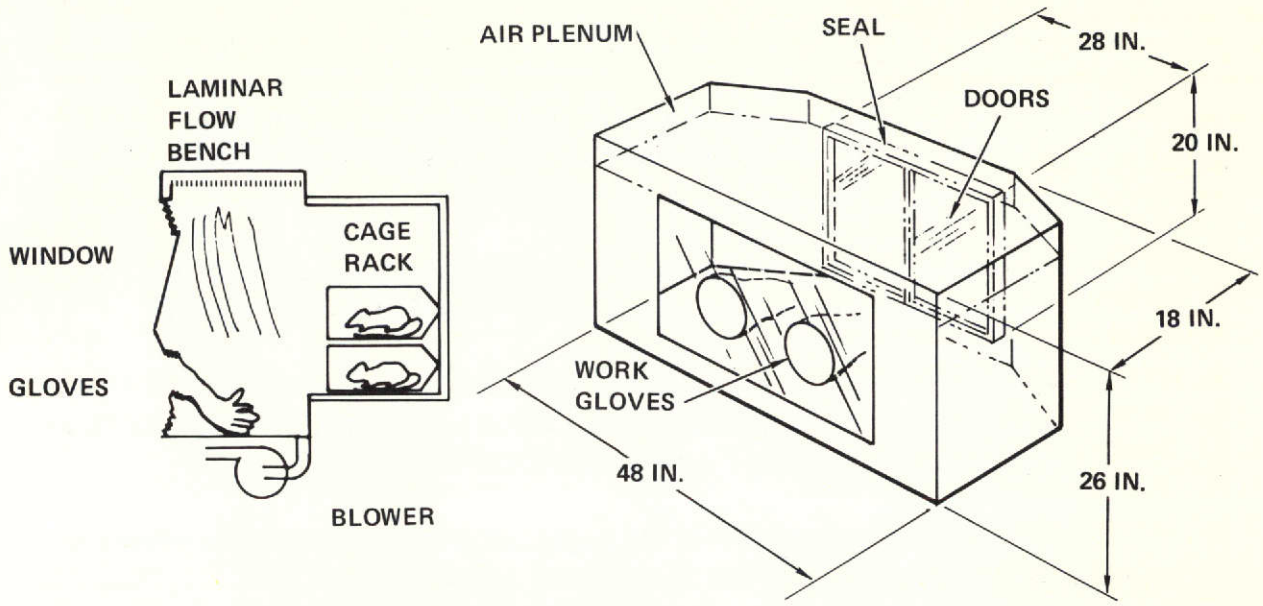

Figure 10-11. LFB Configuration

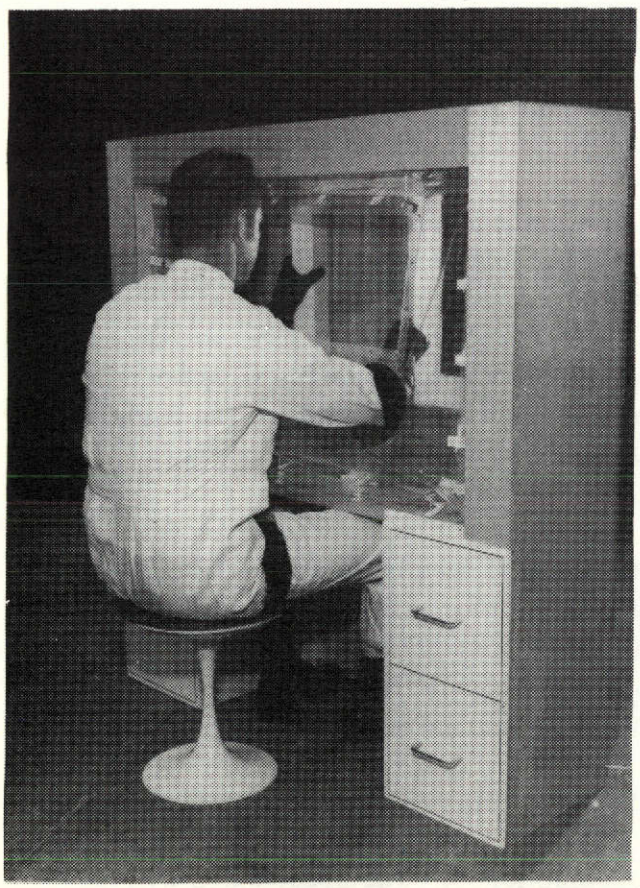

Figure 10-12. LFB for Space Application

Subsequent to the breadboard test program, and engineering prototype will be designed and fabricated. The prototype will undergo engineering and PI evaluation. Final modifications will be made and the design updated for Life Sciences Laboratory baseline acceptance testing using the actual subject organisms.

A tentative schedule of the above tasks is shown in Figure 10-13. The final acceptance testing includes the use by the PI in his laboratory two years piror to the actual flight. Other tests and integration tasks required prior to acceptance for flight operational use will be performed during the same period.

10.4.5 COSTS. The estimated development costs for a flight qualified LFB is $2 million. Unit costs are estimated at $25,000 each. These costs do not include vehicle integration, maintenance/refurbishment, and spares costs.

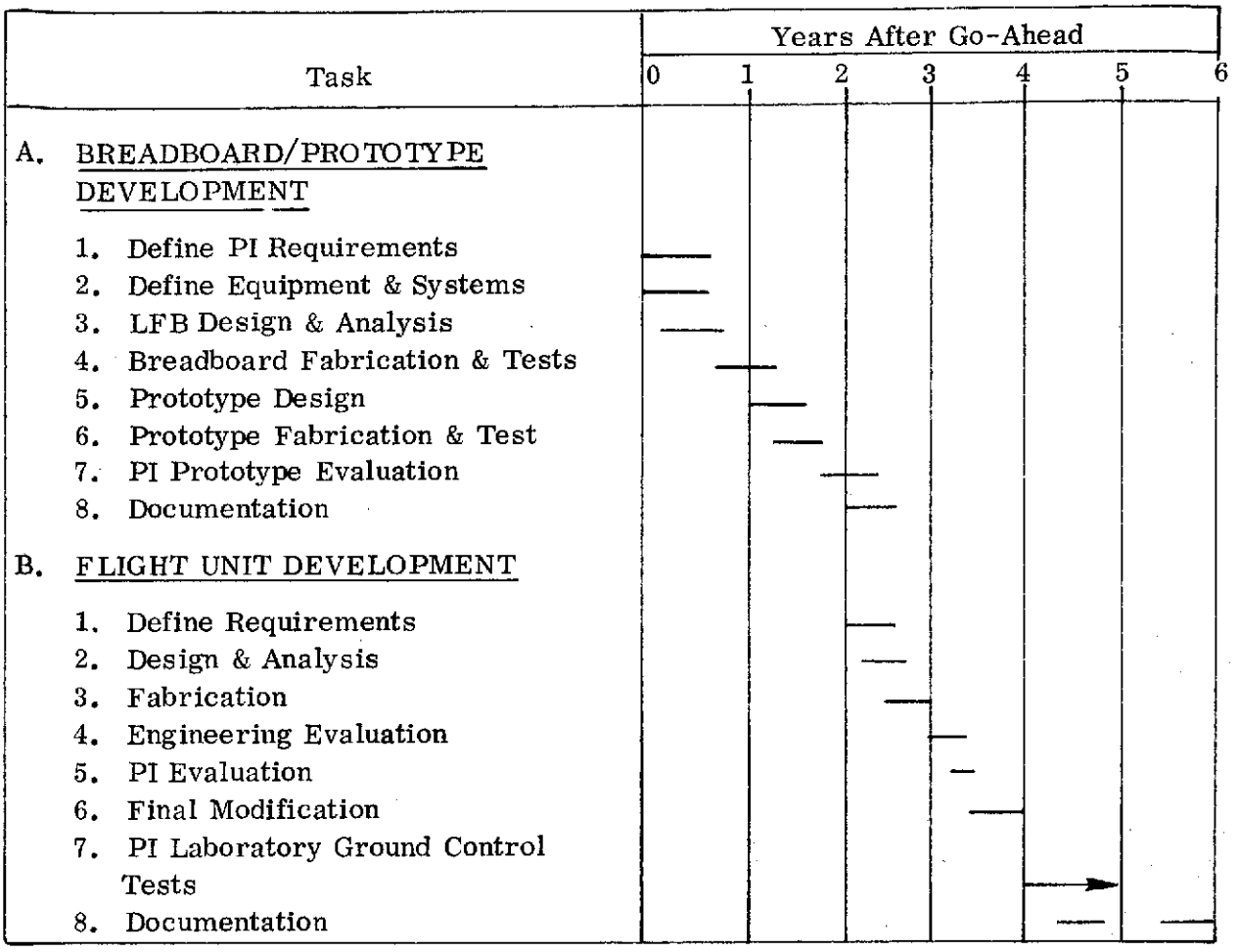

Figure 10-13. Laminar Flow Bench (LFB) Development Schedule

10.5 VIDEO DATA CONTROL UNIT

10.5.1 PURPOSE. This is an electronic device used to control the operation of the video cameras at various organism monitoring sites throughout the Life Sciences Laboratory. It issues commands to the various cameras and receives and processes the data from these cameras.

10.5.2 GENERAL REQUIREMENTS. The Life Sciences Laboratories contain from six to 14 video cameras that monitor various organisms and research phenomena. Most of these cameras operate automatically according to a predetermined data acquisition schedule. Therefore, a device is needed to issue commands to these cameras and process the data received. Processing would include tagging the data with time and identification, and transferring data to recording devices or monitors. It should be noted that these functions might be performed by the data management subsystem computer, depending upon the detailed requirements for camera control and data processing.

One potential requirement of the data processing that has been identified involves a time lapse mode of camera operation. As many as eight of the cameras operate in this mode, and essentially take a still picture of an organism every 10 seconds. These cameras can be moved so that more than one organism can be covered with a single camera. As an example, one camera in an eight-rat-cage module can be designed to move from one organism to another. Thus, each rat would be monitored every 80 seconds. However, any camera can be turned on continuously to monitor a particular organism if required. The data processing required for the time lapse mode of operation involves digitizing the analog video signal and recording it at a slower rate than it is generated. As an example, consider the case of one frame taken at 1/30 second being generated each second. If a standard video recorder were used to store this data, most of the tape would be empty, with information on the single frames occupying 1/30 of the capacity of the tape.

The tape recorder cannot be stopped and started fast enough to conserve this tape, and the amount of tape involved is on the order of thousands of kilograms (see Section 3.2); therefore, an alternative means of storing this data is needed. This can be provided by the video data control unit. This unit can be designed to digitize the intermittent video analog signals and store this data on a quick access storage device. In between this intermittent storage, the data could be transmitted to a tape recorder at a continuous rate, which would result in very little unused recording tape. Again, depending upon the specific requirements, the data management subsystem computer might possibly be able to provide this capability. Because this computer will be used for various computations, data processing, and research program management, it was not assumed to be continuously available for the processing of video data. However, the video data control unit must be thoroughly integrated with the sortie module DMS. It must also be compatible with the video camera mechanical drive systems, the cameras, and the associated electronic systems.

10.5.3 TECHNICAL DESCRIPTION. The functions of the video data control unit could be provided by a digital computer and peripheral equipment, including a quick-access storage device. However, the description of the actual unit has not been determined.

10.5.4 WORK STATEMENT. The general tasks involved in the development of a video data control unit are shown in Figure 10-14. Both hardware and software are required, and the system must be made compatible with the sortie module DMS. Flight-qualified existing hardware may be available that can be used to provide the necessary functions of the data control unit.

10.5.5 COSTS. The development cost for a video data control unit is estimated at $3 million. The unit cost estimate is $150,000. The costs are exclusive of vehicle integration, maintenance/refurbishment or spares costs.

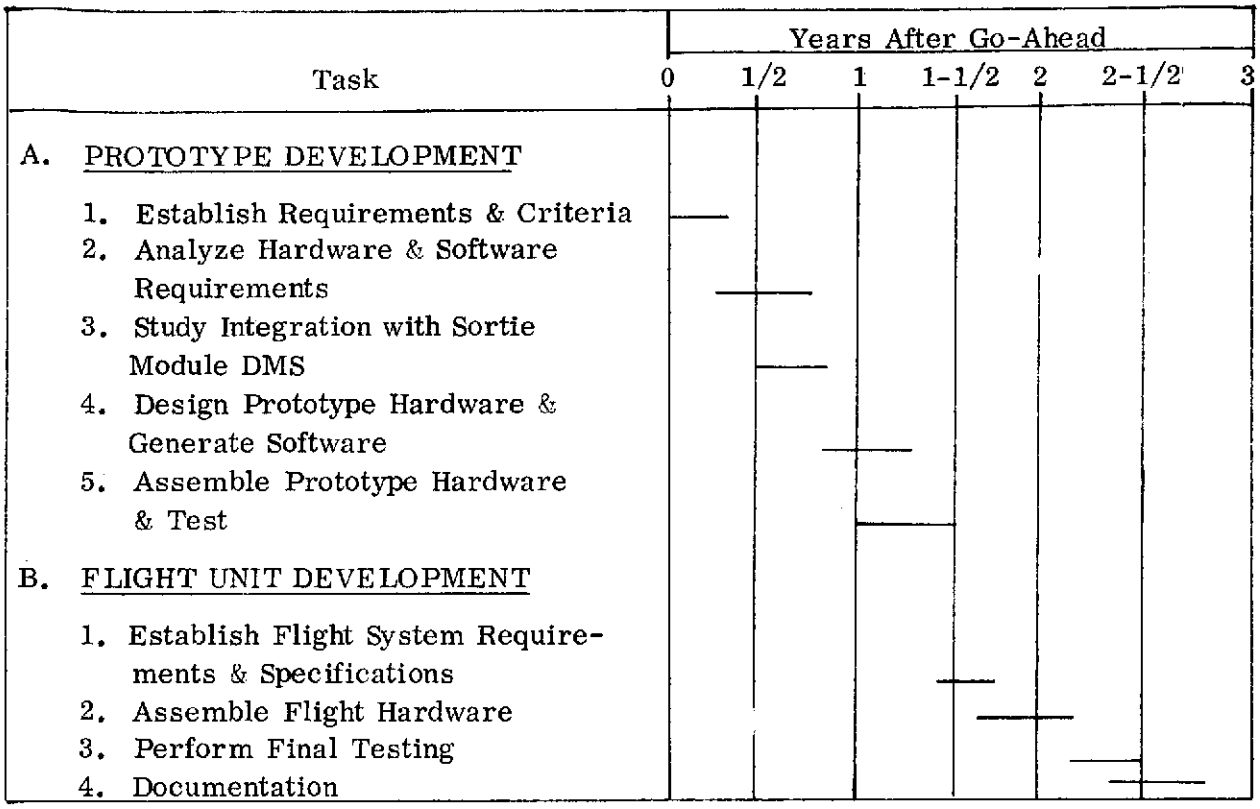

Figure 10-14. Video Data Control Unit Development Schedule

10.6 INTERNAL CENTRIFUGE DEFINITION STUDY

The laboratory concepts (Mini-7 and Mini-30) selected by the NASA Life Sciences Integration Team for study during Task C and D of this program did not include an internal centrifuge.

The need for an internal centrifuge became evident as a result of the second meeting of the Life Sciences Shuttle Sortie Payload Planning Group. The meeting was held in November 1972 at NASA Headquarters, and the following are quotes from the reports of that meeting:

> "A major and very significant position was established during the course of the meeting, namely: a one g control must be available in flight as the only valid method of differentiating biological changes attributable to weighlessness. This position is substantiated by the recommendation of the AIBS contained in their December 15, 1967 report to NASA titled, BioScience Research During Earth-Orbiting Mission. This same requirement has recently (November 1972) been reemphasized by the Space Medicine and Biology Committee of the Space Science Board, National Academy of Sciences.

"The impact of implementing this requirement will be evidenced in the design of the sortie module which now will have to contain a centrifuge or centrifuges. The specifics of the centrifuge(s) designs and the volume requirements will be reflected in the Design Requirements section. The next meeting February 1973 of the working group with different participants will address the engineering and systems approaches to this requirement.

"It is recommended that the National Academy of Sciences Summer Study specifically address the extremely difficult decision as to the advantages and disadvantages of introducing a centrifuge inflight as a 1-g control for biological and/or Life Sciences experiments. This issue has many proponents and opponents, and the need for a positive position and recommendation must be established to design and develop the supporting hardware capability for the shuttle sortie mode."

SECTION 11

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